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SOLAR HEAT—THE TEMPERATURE OF THE SUN.

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[From "Engineering."

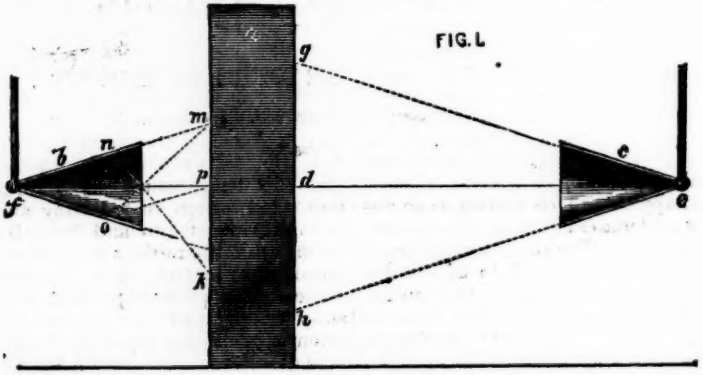
Probably no subject connected with physics, supposed to be known, is so imperfectly understood as the propagation of radiant heat. The recognized law that the temperature imparted to substances exposed to radiant heat, diminishes in the inverse ratio of the square of the distance from the radiating body, is true only of a sphere of perfectly uniform temperature at the surface, if the distance be reckoned from the *centre* of the sphere. The temperature produced by radiation of spheres which are not uniformly heated at all points of their surface, and of other bodies of whatever form, even though they be uniformly heated through the entire mass, we have no means of ascertaining at a distance, however accurately that distance may be known. Nor will it avail if, in addition to the assumed uniform temperature and accurate knowledge of distance, we also know the dimensions and weight of the radiating body. In fine, notwithstanding our knowledge of these elements, an attempt to solve the problem will be fruitless, unless, as before stated, the radiation proceeds from a *sphere* of known dimensions having a perfectly uniform temperature at its surface. Agreeable to the theory of Melloni, however, which theory a high authority assures us has been unanswerably demonstrated by the celebrated Italian, the matter is very simple, viz., the temperature at intermediate points between a heated body and thermometers exposed to and indicating the intensity of the radiant heat, may be determined by squaring the respective distances. The products, it is asserted, will show exactly the inverse ratio of the intensities and consequently the temperature at intermediate points, due to their distance from the radiating surface.

It will be necessary, before entering on a demonstration intended to show the temperature of the sun, to define clearly the law which governs the propagation of radiant heat. I propose, therefore, to examine carefully the merits of Melloni's mode of establishing the infallibility of the propounded theory, that the temperatures imparted to bodies exposed to radiant heat are in the inverse ratio of the distances between the radiating surface and those bodies. Fig. 1 is a diagram showing the leading features of the method adopted by Melloni. *a* represents the side of a square vessel filled with hot water, the faces of which, right and left, are coated with lampblack and in all respects alike. Hollow cones *b c* exactly similar, lined with black paper on the inside and provided with thermometers inserted near the apex, are applied at different distances in opposite directions, their axes being in a line and at right angles with

the faces of the heated square vessel. Melloni states that the temperature indicated by the distant thermometer, *e*, will be precisely the same as that indicated by *f*, however near the latter may be to the vessel, provided the elongation of the sides of the distant cone, *c*, shown by the lines *e g* and *e h*, do not extend beyond the limits of the radiating surface. An inspection of the diagram will convince the attentive observer that because the points, *g* and *d*, of the radiating surface are not equidistant from *e*, the radiant heat which they emit, cannot affect the thermometer, *e*, alike. The extent of the irregularity may be readily determined by squaring the distances *g e* and *d e*, in conformity with Melloni's theory. Now the proportion of these distances as shown by the diagram, is 20 to 19, hence the radiant heat transmittted to the thermometer from the points *g* and *d* will vary in the inverse ratio of the products of the stated numbers, viz., as 361 to 400. This great difference of intensity of heat transmitted to the bulb of the thermometer from different points of the face of the radiaing vessel, will evidently occasion conflicting molecular motion within the contents of the bulb, fatal to precise indication.

The readers of "Heat as a Mode of Motion" may with propriety ask, if the intensity indicated by the thermo-electric pile during the reported experiments was that due to the radiant heat transmitted from *g* in the line of *g e*, or that transmitted from *d* along *d e*? It could not possibly be both, as we have demonstrated that these intensities, when reaching the bulb of the thermometer, vary in the proportion of 361 to 400. It will be seen, therefore, that Melloni's demonstration is quite unsatisfactory. Several minor imperfections inseparable from the method adopted by the Italian physicist might be pointed out, all tending to augment the errors adverted to. The black paper which lines the inside of the hollow cone *b*, as it is very light and incapable of reflecting the radiant heat transmitted by the rays indicated by *k n* and *m o*, will at once become heated. Consequently the air contained within the cone will speedily have its temperature raised by convection, reflecting its heat against the thermometer at *f*, and thereby contributing to disturb the indication already fatally affected by the difference of temperature consequent on the varying intensities of the radiant heat before alluded to. The relative intensities imparted to the black paper within the cone at *o*, and that transmitted to the bulb of the thermometer at *f*, will be determined by squaring the length of the heat rays *p o* and *p f*. The diagram shows that these lengths are as 3 to 5; hence by squaring and inversion we find that the temperature imparted by the radiant heat at *o* will be greater than that at *f* in the proportion of 25 to 9. Black paper being a powerful radiator, while air has very small specific heat, it will be seen that the volume within the cone will be rapidly heated by convection, and hence the thermometer at *f* elevated to a degree far beyond that which it would reach by the direct radiation of the vessel *a*. It will be evident that when a thermo-electric pile is em-

FIG. L.



ployed in place of a thermometer, the disturbing influence of the heat imparted to the volume of air in the cone will be instantaneous. But let us dismiss the consideration of defects of arrangement, and proceed to test the truth of the general theory supposed to have been established by Melloni, namely, that the temperatures imparted to bodies exposed to radiant heat are inversely as the squares of the distances between the radiating surfaces and those bodies. For this purpose let us employ in place of the square vessel containing hot water a block of iron of similar form, heated to such a degree that a thermometer placed at a distance of 30 in. from its face will acquire 40 deg. above the temperature of the surrounding air. (Actual trial has shown that such a block, 36 in. square, heated to 600 deg., is capable of elevating the temperature 40 deg. under the stated conditions.) Having previously ascertained that the thermometer marks exactly 40 deg., let it be moved towards the radiating surface to a point 10 in. distant from the same. What increase of temperature will attend this advance of the thermometer towards the radiating surface? According to the theory the truth of which we are going to test, the increase will be inversely as the square of 30 is to the square of 10, namely, 100 : 900=1 : 9. Accordingly, the elevation of temperature will be $9 \times 40° = 360°$. In like manner the theory shows that if we place the thermometer 5 in. from the radiating face the temperature will increase in the ratio of 25 : 900=1 : 36; hence the thermometer will indicate $36 \times 40° = 1440°$. A further move of 2 in. will place the thermometer 3 in. from the radiating surface, at which distance it will be subjected to an increase of temperature in the inverse ratio of the square of 30 to the square of 3, namely, 9 : 900=1 : 100; the thermometer, therefore, will indicate $100 \times 40° = 4000$. But the temperature of the radiating block of iron is only 600°. The fallacy of the theory under consideration proved by this demonstration is so self-evident that it would be waste of space to prosecute the investigation any further. Melloni's device is, however, important, as it corroborates the established fact that an increase of the surface of the radiator is capable of elevating the temperature of a substance exposed to the radiant heat without increasing the temperature of the radiator; and that the degree of elevation will be in exact proportion to the increased area. The importance of this fact cannot well be overstated. It flatly contradicts certain modern speculations regarding radiant heat, and it affords a landmark which, though it does not point out what we seek, guards against taking the wrong course.

The defects of Meloni's method, and its utter inadequacy to solve the problem under consideration, suggest the question: Is it possible to determine, by calculation, what temperature substances will acquire by being placed at different known distances from the surface of a heated body of known temperature and dimensions, the sides of which are straight and parallel? We are compelled to admit that the question thus presented cannot be satisfactorily answered, because each point of the radiating surface, in consequence of varying distance, transmits a different degree of intensity to the exposed substances. The difficulty of solution is increased on account of the stipulated form; the inferior intensity transmitted from the corners of the radiator rendering the question exceedingly complicated. A radiating plane surface of *circular* form somewhat simplifies the question; yet the difficulty remains of dealing with the inferior power of the heat rays emanating from the circumference, which, when reaching the bulb of the thermometer, occasions the conflicting molecular motion before pointed out. To overcome this difficulty, I have constructed an instrument—shown by the illustrations, Fig. 2 representing a longitudinal section, and Fig. 3 a perspective view (copied from a photograph), in which the radiating surface is concave, forming part of a sphere whose centre is situated near the centre of the bulb of the thermometer employed to ascertain the intensity of the radiant heat. But this expedient of employing a concave spherical surface, every point of which is equidistant from the bulb of the thermometer, prevents any change of distance between the same and the radiator during experiments. I have accordingly introduced 4 distinct discs of varying spherical concavity, with a thermometer placed in the centre of curvature of each. These 4 concave discs form the sides of an open

FIG. 2.

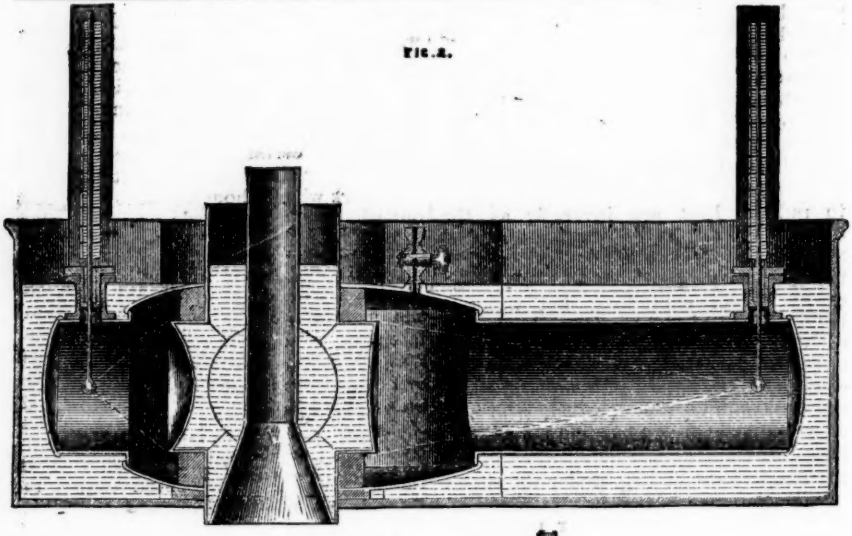
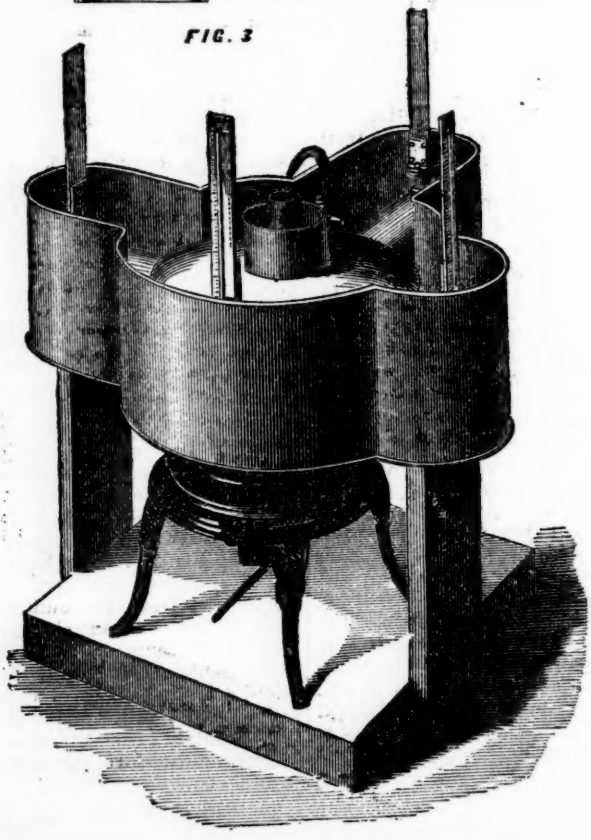


FIG. 3



vessel filled with oil, heated by a gas flame. In order to facilitate comparison, a regular gradation of curvature has been adopted; the radius of the deepest concavity being 3 in., the next being 6 in., then 9 in., and, lastly, 12 in. for the least concavity. It will be evident that, owing to the difference of concavity, each disc will present a different extent of radiating surface, if an uniform size be employed, thereby rendering comparisons between the indicated intensities quite laborious. To obviate this, the diameters of the several discs have been so proportioned that the superficial measurement of each is precisely alike. The disc of the least curvature is 4 in. in diameter; the remaining 3 being respectively 3.982 in., 3.939 in., and 3.777 in. diameter. Much pains have been bestowed on the workmanship in order to obtain concavities of precisely equal areas. The objections urged in connection with the solar calorimeter and actinometer against conducting thermometric observations in the presence of the disturbing influence of the surrounding air, apply with equal force to the apparatus now being considered. Accordingly, the heater, with its 4 concave radiating discs and thermometers, are enclosed in an exhausted chamber, as will be seen by reference to Fig. 2. Evidently, the heat reflected by the sides of this chamber towards the bulbs of the enclosed thermometers, will determine their zero precisely as in the actinometer; hence, it is indispensable that this chamber should be maintained at a constant temperature. This is effected by surrounding the same with an external open vessel filled with water kept at a temperature of 60 deg. Fahr., during experiments. The object of adopting 60 deg. is that of facilitating comparisons with solar intensity, the zero of my actinometer, as stated in a previous article, being also 60 deg. above Fahrenheit's zero. It will be proper to consider briefly the leading properties of the illustrated device. In the first place, the radiating concave surfaces, as well as the bulbs of the thermometers, are surrounded by the ether alone, and therefore cannot suffer any loss of heat by convection. Secondly, the intensity of the radiant heat received from all points of each concave surface will be precisely alike, because those points are equidistant from their respective thermometers. Thirdly, the concave surfaces presenting equal areas, being composed of the same materials of uniform thickness, and being heated by the same medium, will emit an equal amount of heat. Fourthly, as the several thermometers are exposed to the radiation of a surrounding vessel kept at 60 deg., they will acquire that temperature before fire is applied to the heater. In consequence of this, the increase of temperature, after heating, will furnish a true comparative measure of the force of the radiant heat transmitted from the concave radiators to the bulbs of the thermometers.

The prevailing notion that there is a concentration of heat in the focus of spherical radiators, will be urged as an objection against the described method of measuring radiant heat. A careful examination of this question will be necessary, as it is intimately connected with solar radiation and solar temperature. Fig. 4 represents a concave spherical radiator, *c* being the focus, *o c* the axis, and *a b* section of the radiator. Agreeable to the accepted theory of radiation, rays of heat are projected in all directions from every point of the radiating surface. In order, therefore, to demonstrate that there is no concentration of heat in the focus, we have merely to draw radial lines representing the heat rays, from points *d* and *f* on the concave surface, as shown on the diagram. It will be seen on close examination that there is only a single ray, *d c*, emitted from the point *d*, which is directed towards the focus *c;* the ray *f c* being the only one directed from the point *f*. The other heat rays from the points *d* and *f*, diverge in all directions, and intersect every part of the field *k l;* thus dispersing the radiant heat nearly uniformly over a very large surface. The curve *c n* struck from the point *f*, clearly shows that all the heat rays below c, projected from *f*, are shorter than those directed to the *focus* from the same point, and therefore impart a higher temperature to the plane, *k l*, than that transmitted to the focus. It will be needless to enter on a detailed computation of the temperature at the intersections of the various rays with the plane, *k l*, as a mere inspection of the diagram distinctly shows that the focus, *c*, receives no increase of heat on account of being the centre of the spherical radiator. Indeed,

if we substitute a *plane* circular disc extending from *a* to *b*, a greater amount of heat will be transmitted to a thermometer placed at *c*, than with the spherical surface represented; the only important difference being that a thermometer placed in the focus of the latter receives an equal degree of heat from each point of the concave surface.

FIG. 4.

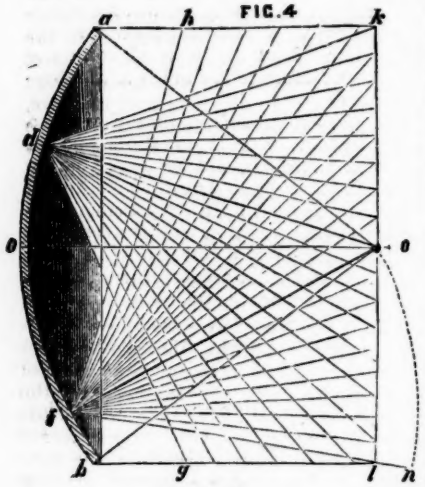
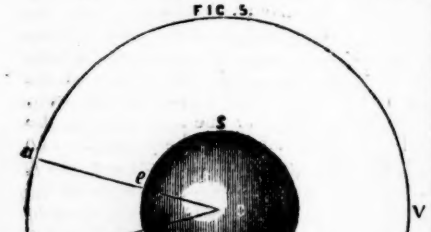


FIG. 5.



Investigations conducted by means of the illustrated instrument prove that the intensity of heat transmitted by the radiation of concave spherical surfaces of equal temperature, presenting equal areas and having different curvature, is in the inverse ratio of the square of their radii, provided the substance which receives the radiant heat is placed in the focus of the radiating surface. This important fact in connection with the previous demonstrations showing the fallacy of the propounded theory that the intensity of radiation diminishes in the inverse ratio of the square of the distance, between radiators and the recipients of their radiant heat, enables us now to consider the proposi ion contained in our introductory remarks, viz., that the assumed law is true only of a sphere of perfectly uniform temperature at the surface, if the distance to the recipient of the radiating heat be reckoned from the *centre* of the heated sphere. Suppose that *s*, Fig. 5, represents a solid sphere of metal maintained at a constant temperature and suspended in the centre of an exhausted metallic spherical vessel, *v*, the size of which is much greater than that of the solid sphere; *c a* and *c b* being radial lines drawn from the mutual centre, *c*, to the circumference of the exhausted vessel. The heated sphere being maintained at an uniform temperature while the spherical vessel is exhausted, and thereby freed from any disturbing influence of currents of air, it will be evident that the intensity of radiant heat, thus transmitted from the sphere through the ether alone, will be alike at every point of the surface of the surrounding spherical vessel. Obviously, the temperature resulting from radiation against the latter will be less than that of the central sphere in proportion to the area presented by each. In other words, *the temperature will be inversely as the areas of the two spheres.* On the soundness of this proposition depends the correctness of the accepted doctrine relating to the propagation of heat and light through space. The remarkable fact must not be overlooked, that this proposition takes no cognizance of *distance;* and that it enables us to determine the temperature of the central sphere merely by comparing the relative *areas* and ascertaining the degree of heat which is transmitted from the central to the surrounding sphere; the intervening space, whether it be 1 mile, or 1,000 miles, being an element excluded from our calculation.

That rays of light and heat meet with no appreciable resistance in their passage through the ether is an irresistible inference to be drawn from the fact that the

intensity depends solely on the *area over which the rays are dispersed.* The common expression that "the intensity of light and heat varies inversely as the square of the distances" leads to the supposition that *distance* is an element to be taken into account in estimating the intensity of radiant heat. That this is an error will be readily perceived if we reflect on the fact, just referred to, that the intensity of the rays diminishes in the *exact* proportion to the areas over which they are dispersed. It is self-evident that if distance, *per se*, in any way affected the question, the intensities could not thus depend solely on the extent of the *areas* over which the rays are diffused. I will endeavor to show, at the proper time, that the force of solar radiation would be in the ratio of the square root of the cubes of the distances, if dispersion did not alone determine the question. Much misapprehension would be prevented if the law relating to radiant heat were thus expressed: *The intensities are inversely as the areas over which the rays are dispersed.* Sir Isaac Newton, referring to the intensity of the sun's radiant heat at different distances, thus clearly defines the question: "The heat of the sun (at various distances) is as the density of its rays." He also states that the densities of the diverging rays are "reciprocally as the square of the distance from the centre of the sun," a fact which evidently has nothing to do with the main proposition, as it simply results from certain geometrical relations, viz., that the areas of transverse sections of a cone are as the square of the distances from the apex.

I will now proceed to show why the theory of Newton, supposed to have been proved by Melloni, is true, under certain conditions, as regards an uniformly heated sphere, although fallacious, under all circumstances, as regards plane surfaces. Referring again to Fig. 5, let us assume that the sphere S represents the sun, the semi-diameter of which is 426,292 miles; and that *a b v* represents the earth's orbit reduced to a circle whose radius corresponds with the earth's mean distance from the sun's centre, 91,430,000 miles. Now the arc *e f* is to the arc *a b* as the radial line *c e*, representing the sun's radius, is to *c a*, representing the earth's distance from the sun's centre. Agreeable to the stated dimensions, therefore, *c e* is to *c a* as 1 to 214.44; hence, regarding *a c b* as a cone, the area of *e f* is to that of *a b* as 1 to the square of 214.44=45,984. Accordingly, the temperature of the heated central sphere S will be 45.984 times greater than the temperature which it imparts by radiation to the surrounding sphere *a b v.*

We have now fully established the fact that although the extent of the radiating and recipient surfaces, in connection with the temperature of the former, determines the temperature transmitted to the latter, wholly independent of distance, yet, as regards the sun, the temperature produced by the radiant heat of his rays, is inversely as the square of the distance reckoned from his *centre*, the same law applying to all spheres having an uniform temperature at the surface.

The law which governs the propagation of radiant heat being thus established beyond contradiction, we may at once enter upon the consideration of the sun's temperature. Evidently this problem cannot be solved unless we know the diameter of the sun, the distance between the surface of the earth and the centre of the sun, and also the intensity of the sun's radiant heat at the point where the rays enter our atmosphere. By means of thermometers we can ascertain the temperature of substances exposed to solar radiation, and by deducting from the same the temperature of the surrounding atmosphere, we can determine the intensity of solar heat near the surface of the earth. Adding to this the loss which the radiant heat sustains during the passage of the rays through the atmosphere, we are enabled to estimate the intensity of solar radiation at the boundary of the earth's atmosphere, provided the thermometric observations are correct. The employment of the actinometer in place of the ordinary thermometers relieves us from all uncertainty in regard to thermometric determinations. In the first place, its indication is not affected by changes of terrestrial temperature of any kind, hence it may be employed at all seasons. Secondly, it assigns to solar intensity a fixed position on the scale, the thermometric interval which marks that intensity being affected alone by *change of distance between the sun and the earth.* Of course, in all computations based on observation, due allowance must be made for the sun's zenith distance.

The eccentricity of the earth's orbit being 0.01679, the distance from the sun during the summer solstice will be 0.03358 greater than at midwinter. This difference, fully 3,070,000 miles, is so considerable that actinometer observations carefully made at the two extreme positions of the earth in aphelion and perihelion, furnish data which enable us to compute with almost positive certainty the minimum temperature of that part of the envelope of the sun the radiant heat of which we receive.

Experienced observers are well aware that it but seldom happens on the eastern portion of the American continent, that the atmosphere is sufficiently free from vapors at the summer solstice to present a perfectly clear sun. During the period of my investigation of solar heat, the weather at midsummer has not been favorable for actinometer observations. I have accordingly been compelled to compute the sun's intensity at the summer solstice from observations made during certain periods before and after the passage of the aphelion. The solar calorimeter, which indicates the sun's dynamic energy very accurately, has been of much service in corroborating and checking the computations alluded to. Future observations in more favorable localities, may possibly call for some modification, but not of sufficient magnitude to affect the question practically. The mean of the several observations which I have made, and of the computations based thereon, is somewhat over 6 deg. Fahr. increased intensity of solar radiation consequent on the diminution of the earth's distance from the sun during our winter solstice. The eccentricity of the earth's orbit, as before stated, is 0.01679; the ratio of greatest and least distance from the earth to the centre of the sun will accordingly be as 1.01679 to 0.98321. The temperatures being inversely as the square of the distances from the centres of spheres uniformly heated at the surface, we ascertain, by squaring the amounts last presented, that the ratio of temperatures on the ecliptic at our summer and winter solstices will be, in round numbers, as 966 to 1033. The actinometer observations, recorded in a previous article, prove that the maximum solar intensity on the tropic of Cancer, at midsummer, is 67.2 deg.; while the diagrams furnished at the same time, show that the loss of intensity of the sun's rays in their passage through the atmosphere, on the ecliptic, is 0.207 or 17.64 deg. Accordingly, the temperature produced by solar radiation at the boundary of the atmosphere when the earth passes the aphelion (summer solstice), will be 67.20 deg. + 17.64 deg.=84.84 deg. Fahr. The square of the distances between the sun and the earth during the summer and winter solstices being, as already stated, in the ratio of 1033 to 966, we ascertain by analogy that the temperature at the boundary of the atmosphere will be 90.72 deg. when the earth passes the perihelion (winter solstice), viz., 966 : 1033=84.84 deg. : 90.72 deg. Hence, the increase of intensity of solar radiation caused by the eccentricity of the orbit, and the consequent approach of the earth towards the sun during the winter will be 90.72 deg. – 84.84 deg.= 5.88 deg. Fahr. The readers of "Outlines of Astronomy" are aware that Sir John Herschel assumes that 23 deg. Fahr. is the least variation of temperature which can be attributed to the variation of the sun's distance. The reasoning on which this remarkable assumption is based is incompatible with the ascertained intensity of the sun's radiant heat, as will be shown hereafter.

The frontispiece of the present number represents an instrument for ascertaining the temperature of the sun. At first sight it will appear futile to undertake to measure temperature at a distance of 90,000,000 miles; but in view of the fact that the sun has been weighed by an instrument consisting principally of four leaden balls less than 10 in. in diameter, the attempt cannot justly be deemed absurd. The reader will remember that in the celebrated Cavendish experiments, afterwards repeated by Baily and others, the weight of the earth—on which the weight of the sun is based—was ascertained by measuring the attractive force of two spheres of lead weighing 174 lbs. The delicate nature of the experiment may be inferred from the fact that the ascertained attractive force was found to be only $\frac{1}{4300}$ of a grain. The illustrated device by means of which the temperatnre of the sun may be measured, involves no such nicety.

Before entering on a description of the solar pyrometer, it will be necessary to call to mind the previous argument, which demonstrates that the law relating

to the radiant heat of spheres, is also applicable to concave spherical surfaces if the substances exposed to their radiant heat be placed in the centre of curvature. The argument referred to, also proved that the temperature produced by the radiant heat transmitted by concave radiators of equal temperatures, at equal distances, is directly as their areas. Melloni and Leslie's experiments, conducted in the presence of the disturbing influences of atmospheric air, not being deemed sufficiently accurate to prove the correctness of the assertion referred to, the construction of the pyrometer now presented has been so modified as to prove conclusively that under the stated conditions the temperatures correspond exactly with the areas.

The frontispiece represents a longitudinal section through the vertical plane, and a photographic perspective of the solar pyrometer, modified for the purpose alluded to. As will be seen by referring to the longitudinal section, the instrument is composed of four principal parts: 1. The heater, consisting of a cylindrical vessel placed vertically, having a spherical bottom and open top; an enlargement representing a truncated cone being formed near the middle, the ends of which are concave and spherical. 2. A conical vessel surrounded with a double casing secured to the base of the central enlargement of the heater. 3. A cylindrical vessel secured to the opposite end of the said enlargement, also surrounded with a double casing. 4. A furnace enclosing the lower end of the heater. The spherical concavity at the base of the conical enlargement of the heater, the radius of which is 18 in., presents an area of 78.84 square inches. The opposite spherical concavity, the radius of which is 9 in., presents an area of $\frac{78.84}{4} = 19.71$ sq. in., its diameter being very nearly 5 in. Thermometers are applied at the *foci* of the spherical concavities, their bulbs being so arranged that only one-half of the area is exposed to the radiant heat, the other half being surrounded by a non-radiant substance. It is proper to observe that thermometers employed in measuring the intensity of radiant heat, must be so arranged that no part of the bulb which is not acted upon by the heat rays projected from the radiator, should be permitted to part with any of the heat received, excepting by radiation in the direction of the radiant body. This is an indispensable condition which must be fulfilled in order to secure a correct indication. Accordingly I have resorted to various expedients to prevent loss of heat from the shaded side of the bulb, and find that surrounding the latter with a casing of burnished silver provided with a suitable opening on the front side, is the most efficient means of attaining the object. The cylindrical as well as the conical chamber of the pyrometer containing the thermometers, are connected by suitable pipes with an air-pump by means of which the air is carefully withdrawn; a current of water being circulated through the double casings when the instrument is in operation. With reference to the heater, it is only necessary to observe that, being open at the top and charged with pure water, it will be maintained at a constant temperature of nearly 212 deg. when the furnace is in action.

The principle of my solar pyrometer is that of ascertaining the intensity of the heat of the sun by comparing the temperature produced by the radiant heat of a concave spherical radiator of 10 in. diameter, at a distance of 18 in. from its face, with the temperature produced by the radiant heat of the sun, a sphere of 832,584 miles in diameter, at a distance of 91,430,000 miles from its centre. The radiant heat in both cases is transmitted through ether; in the former to the surface of the bulb of a thermometer; in the latter to the boundary of the earth's atmosphere. The law which governs the propagation of radiant heat through ether, is as absolute as the law of gravitation, whatever be the distance; hence the pyrometer under consideration, in which the radiant heat is propagated a distance of 18 in. through ether, is as competent to determine the temperature of the sun as the Cavendish leaden spheres acting at a distance of 8.85 in. to determine his weight. The chances, however, of an exact determination are greatly in favor of the pyrometer. In the first place, while the area of the concave radiator of the pyrometer is to the area of the great circle of the sun as $1 : 2871 \times 10^{16}$, the weight of the attracted vibrating leaden ball employed in the Cavendish experiments is to that of the weight of the earth as $1 : 7617 \times 10^{21}$, thus showing a

difference of 1 : 265,000 in favor of the pyrometer. Besides, the difference of distance through which the radiant and the gravitating forces act, is in favor of the pyrometer, in the ratio of 18 to 8.85. But these considerations, however important on account of the greater difference of the magnitudes involved, may be considered trifling in comparison with the directness of the means by which the solar pyrometer solves the problem, contrasted with the indirectness, exceeding complication, and nicety, involved in the Cavendish experiments. In the solar pyrometer we only require a correct indication of the temperature of the radiating concave spherical surface, and of the temperature transmitted to its focus; together with an accurate measurement of the distance of that focus, and of the area of the radiating surface. These points being determined with exactness, we may enter upon and carry out our computation without introducing a single correction. How different the Cavendish experiment, with its numerous disturbing elements depending on barometric and thermometric conditions and changes, all influencing a gravitating force amounting to only $\frac{1}{13000}$ of a grain! We lack space to present an account of the almost insuperable difficulties which were surmounted in those remarkable experiments, which, for ingenuity, care, and perseverance stand unequalled in the annals of physics. This brief allusion, however, to experiments which satisfactorily determined the weight of the earth, and thereby the weight of the great central body of the planetary system, has been deemed appropriate as a contrast. The directness, facility, and certainty of measuring the temperature of the sun by the means we are now considering, would scarcely be appreciated without calling to mind the method adopted for ascertaining its weight.

Referring to the construction of the solar pyrometer and its apparently ponderous character, practised experimentalists are aware of the difficulties of conducting investigations in which a perfect and continuous vacuum is wanted; when heat and cold, as in this case, are brought into close proximity, weight and substantial proportions, they know, cannot be avoided. They also know that the indispensable condition in the solar pyrometer, of maintaining a constant temperature of the concave spherical radiator, is not easily fulfilled; and that nothing short of an *open* heater containing a fluid which readily evaporates, and the application of an excess of heating power, will accomplish the object in view. Evidently the loss occasioned by radiation cannot be exactly made good by the most delicate mechanical contrivance; but by applying an excess of heat in the furnace, the fluid which regulates the temperature of the radiator will be prevented from falling below the boiling point; and since the heater is open, the steam formed will carry off superfluous heat, and thus maintain the fluid at the desired uniform temperature. The exhausted chambers which contain the thermometers, must of course be maintained at a constant temperature, the least fluctuation being fatal to accurate indication of the intensity of the heat transmitted by the radiators. In order, therefore, to keep up the necessary constant temperature, a current of water (obtained from the street main) is circulated through the double casings which surround the exhausted chambers. By this expedient, in connection with the perfectly uniform temperature maintained in the heater, it has been easy to ascertain with critical nicety the temperature produced by the radiant heat transmitted from the spherical radiator to its focus. Regarding area and curvature, accurate workmanship alone will insure what is requisite; but the position of the thermometer, the placing it at the proper distance with reference to the focus, involves many considerations; indeed this is the most difficult point connected with the management of the solar pyrometer. Obviously it would not be correct to place the centre of the bulb in the focus of the radiator, as that would bring the face of a bulb of $\frac{1}{2}$ in. diameter $\frac{1}{4}$ in. in advance of said focus; nor would it be proper to carry the bulb so far back that its face would intersect the focus. The focal distance being 18 in., it will be found that placing the bulb half way between these two positions will cause an error of fully 0.007. Conflicting indication, it should be observed, is unavoidable, since every part of the exposed half of the bulb cannot be equidistant from the face of the concave radiator; but this notwithstanding, there is a distance at which the indi-

cation of the thermometer will be precisely the same as if its entire contents were concentrated in the focus of the radiators. This position has been determined, but an account of the process would occupy too much space.

In view of the foregoing explanations, and granted that we know the distance and diameter of the sun, I assert that the solar pyrometer enables us to ascertain the sun's temperature.

The hitherto accepted doctrine, that the intensity of radiant heat is directly as the area of the radiators, for equal distances, was shown in a previous article to be fallacious, because the radiant heat transmitted from the boundaries of plane radiators, *when enlarged*, becomes enfeebled by distance and the consequent dispersion of the heat rays, in the ratio of the squares of the distance between the radiator and the recipient of the radiant heat. The solar pyrometer being based on the assumption that the intensity of the radiant heat transmitted from concave spherical surfaces is directly as the areas of such radiators, it was deemed necessary to establish the correctness of this assumption, and for that purpose the solar pyrometer has been modified as before mentioned. The lesser radiator attached to the conical enlargement of the heater (see illustration), and the cylindrical chamber enclosing the same, have accordingly been added to the instrument. It has already been stated that the area of the spherical radiator enclosed by the conical chamber is exactly four times greater than that of the opposite radiator, and that the radius of the latter is exactly one-half of the radius of the former. The demonstration already referred to established the fact that in concave spherical radiators presenting equal areas, the radiant heat transmitted is in the inverse ratio of the square of the distances if the substance exposed to the radiant heat be placed in the focus of the radiator. It follows from this demonstration that, for equal area, the intensity of the radiant heat transmitted to the focus of the lesser radiator, will be four times greater than the intensity of the radiant heat transmitted to the focus of the large radiator. But the area of the latter is exactly four times greater than the area of the former, while the thermometers in both chambers are exposed to the radiation of surfaces heated by the same medium, and therefore of precisely equal temperatures. At the same time these thermometers radiate against surfaces maintained at a constant temperature, by the reliable expedient of employing a powerful continuous current of water. Consequently, if my assumption be correct, the enclosed thermometers, although exposed to radiators of different area, should indicate precisely equal temperature. Actual trial showing that such is the case, the correctness of my assertion, that the intensity of radiant heat transmitted to the *foci* of concave spherical radiators of equal curvature is directly as their area, must be accepted as fully established.

The leading features of the solar pyrometer having thus been explained, I will now state briefly the result of an experiment made while the atmospheric pressure was balanced by a 29.91 inch column of mercury, the temperature of the water in the heater being precisely 212 deg. Besides the advantage of a definite indication of heat, the temperature of the current of water circulated through the casing surrounding the exhausted conical chamber did not fluctuate at all during the experiment; the thermometer inserted in the exit pipe continuing to indicate steadily 48.1 deg. Consequently, before the fire was applied in the furnace, the enclosed thermometer, the surrounding chamber, the water contained in the heater, and the radiator, were all brought to a temperature of 48.1 deg. The result of applying fire to the furnace and bringing the water in the heater to the boiling point was that of increasing the temperature of the spherical radiator from 48.1 deg. to 212 deg., difference=163.9 deg.; the temperature of the focal thermometer at the same time increasing from 48.1 deg. to 60.3 deg., difference=12.2 deg.

Experiments instituted to determine the important question of radiant power have failed to show that the heat-rays emitted by a metallic surface, prepared as in the solar pyrometer, have less energy in proportion to the temperature of the metal than the heat-rays emanating from incandescent carburetted hydrogen in proportion to its temperature. Indeed, the experiments prove that, relatively, less energy is possessed by the heat-rays of the latter, transmitted through air,

than that possessed by the rays from the metallic surface transmitted through a vacuum. No doubt the difference is owing to the refrigerating effect of the surrounding air during the experiments with the flame. Trials to ascertain the radiant power of incandescent gases, within a vacuum, have not been attempted on account of the intricacy involved in constructing an apparatus capable of maintaining a solid flame within an exhausted vessel. The question is, however, not of vital importance, as it is possible to subject the correctness of the indications of the solar pyrometer to a more rigorous test than that of comparing the radiant power of metallic substances and incandescent gases. Our knowledge of the distance and diameter of the sun, and of the intensity of solar radiation at the boundary of the earth's atmosphere—demonstrated in a previous article—enable us to calculate with almost perfect accuracy the temperature of the sun, exclusive, of course, of the energy which is lost during the passage of the rays through the solar atmosphere beyond the point of maximum intensity.

Before applying this test, let us first determine the temperature of the sun in accordance with the indications of the solar pyrometer. As the principle of the instrument calls for the employment of a concave radiator of spherical curvature, it will be evident that in comparing its indication with solar radiation, we must not overlook the fact that the sun, in place of presenting a concave spherical surface, the focus of which is situated at the boundary of the earth's atmosphere, presents a convex semi-spherical face. In consequence of this—the sun being 852,584 miles in diameter—his limb will be 426,292 miles further off than the nearest point of his face. The eccentricity of the earth's orbit being 0.01679, while the mean semi-diameter is 91,430,000 miles, it follows that during the summer solstice the distance from the earth to the centre of the sun will be 92,964,800 miles. Deducting the radius of the sun, we ascertain that the distances to the sun's limb, and to the centre of his face, are respectively 92,964,800 and 92,538,500 miles. Inverting the square of these distances, it will be found, therefore, that the intensity of radiation from the limb of the sun, compared with the central part, suffers a reduction of 0.0086. The temperature at the boundary of our atmosphere being 84.84 deg., it will thus be seen that the reduced intensity under consideration amounts to $0.0086 \times 84.84° = 0.51°$ Fahr. The observed diminution of the intensity of the radiant heat emanating from the limb of the sun being more than this, it will be seen that we may, without material error in our calculations, regard the entire surface represented by the area of the great circle of the sun as being equidistant—92,964,800 miles—from the earth.

It results from previous demonstrations that the temperature of spherical radiators transmitting equal intensities to their *foci*, are inversely as the square of the sines of half of the angles which they subtend, that is, the angles formed by the axis of the radiator and the heat rays projected from the circumference to the *focus*. We know from previous explanations that, owing to the great distance in connection with the diminished intensity of the rays emitted by its limb, the radiant power of the sun will be identical with that of a spherical radiator whose focus is situated at the boundary of the earth's atmosphere. Consequently, as the spherical radiator of the solar pyrometer, the temperature of which is 163.9 deg., transmits to its focus an intensity of 12.2 deg., we are enabled to calculate what temperature the sun must possess in order to transmit an intensity of 12.2 deg. to the boundary of our atmosphere. The angle subtended by the sun is 32 min. 1 sec.; that subtended by the radiator of the pyrometer 32 deg 15 min., the ratio of the square of the sines of half of these angles being 1 : 3567.7. Accordingly, the sun, in order to produce by its radiant heat a temperature of 12.2 deg. at the boundary of the atmosphere of the earth, must possess a temperature 3567.7 times greater than that of the spherical radiator of the pyrometer. This latter temperature being 163.9 deg., that of the sun cannot be less than $3567.7 \times 163.9 = 584746$ deg., in order to transmit an intensity corresponding with a thermometric interval of 12.2 deg. on the Fahrenheit scale. But solar intensity at the boundary of our atmosphere, as demonstrated by my actinometer observations, is 84.84 deg., hence $\frac{84.84}{12.2} = 6.95$ times greater than that transmitted by the radiator of the pyrometer to its focus. The temperature

of the sun, therefore, cannot be less than $6.95 \times 584746 = 4{,}063{,}984$ deg. Fahr.

It will be recollected that the previous demonstration relating to the sun's temperature, established with as much certainty as any proposition in the "Principia," that the temperature produced by the radiant heat transmitted by a sphere of uniform temperature at the surface, is to the temperature of the sphere itself inversely as the square of the radius to the square of the distance from the centre to the point exposed to the radiant heat. The distance between the sun and the earth at the summer solstice being 92,964,000 miles, we find by dividing this distance by the sun's radius, 426,292 miles, that the ratio of distance and radius is 218.1: 1, and hence the ratio of the squares, as 47567: 1. Consequently, the temperature of the sun must be 47,567 times greater than the temperature produced by solar radiation at the boundary of the earth's atmosphere. That temperature being 84.84 deg., the sun's temperature cannot be less than 47567×84.84 deg.$=4{,}035{,}584$ deg. Fahr. Thus the previously demonstrated temperature of 4,063,984 deg. Fahr., based on the indications of the solar pyrometer and the subtended angles, differs only 0.007 from the computations just presented. The methods by means of which these results have been reached differing entirely, each being founded on sound physical and mathematical principles, we cannot reasonably question the reliability of the determination, although the established temperature is inconceivably high. Nor can it be questioned that the actual temperature at the point of maximum intensity is still higher, since the rays in passing through the outer strata must suffer a loss of energy corresponding with the force expended in creating the observed currents in the solar atmosphere. Referring to these currents, the extraordinary rapidity of which, on dynamic grounds, is incompatible with great density or weight, it is proper to call attention to the exceeding lightness of the solar atmosphere, resulting from the high temperature we have demonstrated in conjunction with the small specific gravity of hydrogen. Both obviously contribute to reduce in a very high degree the density of the superincumbent gases, thereby neutralizing the attraction of the immense mass of the sun. Indeed, it may be shown by an easy calculation, that owing to the high temperature—sufficient to expand atmospheric air 7,000 times—together with the small specific gravity of the medium itself, a depth of solar atmosphere of 50,000 miles inside its boundary, will exert no more pressure than the earth's atmosphere, nothwithstanding the superior attraction of the sun's mass. Let us examine this subject briefly. Lockyer assumes that the sun's atmosphere extends 80, 00 miles above the visible surface. Now, although we may fall short in our estimate of the sun's maximum intensity in consequence of the unknown amount of retardation suffered by the rays, there is no difficulty in determining the temperature at the point which terminates the solar atmosphere, since beyond the latter the rays are not subjected to any appreciable loss of energy. Adding, then, 80,000 miles to the radius of the sun, we ascertain that the diameter of the sphere forming the boundary of the solar atmosphere is $852{,}584 + 160{,}000 = 1{,}012{,}584$ miles. A sphere of such diameter subtends an angle of 38 min. 2 sec. The radiator of the solar pyrometer, it will be recollected, subtends an angle of 32 deg. 15 min. The ratio of the sines of half of these angles is 1: 50.22; and therefore the ratio of their squares, 1: 2522.04. Accordingly, the temperature at the boundary of the sphere under consideration (1,012,584 miles in diameter) will be 2522.04 times greater than the temperature of the radiator of the pyrometer, viz., $163.9° \times 2522.04 = 413{,}362°$ Fahr. But the recorded observations and experiments show that the temperature produced by solar radiation at the boundary of our atmosphere is 6.95 times greater than that transferred by the radiator of the pyrometer to its focus; hence the temperature will be $6.95 \times 413{,}362° = 2{,}872{,}865°$ Fahr. at the point where the solar atmosphere terminates. If, in place of basing our computation on the indication of the solar pyrometer, we adopt the mode applicable to spheres uniformly heated at the surface, the temperature at the boundary of the solar atmosphere will, on grounds before explained, be reduced 0,007, hence 2,852,783 deg. It will be preferable to adopt 2,872,865 deg. on the supposition that future actinometer observations in localities where the sun is clear, may prove that my determination

of the intensity of solar radiation at the atmospheric boundary, viz., 84.84 deg. Fahr., is somewhat under-estimated.

The mean of the stated temperatures 4,063,984 deg. and 2,872,865 being 3,468,429 deg., we may safely assume that the mean temperature of the solar atmosphere between the point of maximum intensity and the termination of the distance of 80,000 miles from the visible surface of the sun, assumed by Lockyer, exceeds 3,468,429 deg. Fahr.

Our space only admits of an allusion to the speculations and calculations which have been published of late by certain savans relative to solar temperature. Among these, Zöllner's calculations may be mentioned as the most singular, being based on the height of the observed solar protuberances. Practical men who have witnessed the explosions in closed reverberatory furnaces, which take place when a dense mass of incandescent coal gas, resting on the fused metal, is suddenly ignited by the admission of oxygen, will probably attribute the solar protuberances to a very different cause from that imagined by Prof. Zöllner. They will assert that the observed explosions in the solar atmosphere are quite possible without sending up gas from a depth of 139 geographical miles through the "ausströmungsöffnung," supposed by the German physicist. The reader may have noticed that some of the savans alluded to have attempted to set limits to solar temperature on chemical and dynamic grounds, insisting that the temperature of the sun is under 60,000 deg. Fahr. All such speculations are futile, in view of the fact which we have established, that a heated sphere subtending an angle of only 32 min., at a distance of 90,000,000 miles, cannot, unless raised to a temperature of several millions of degrees, transmit radiant heat sufficiently intense to cause an elevation of temperature 84 deg. Fahr. at the stated distance.

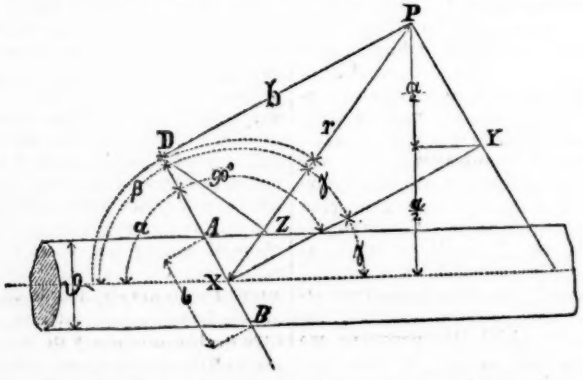
A SIMPLE FORMULA FOR DETERMINING THE RESISTANCE OF AXLES.

By H. VON REICHE.

Translated from "Zeitschrift des Vereins Deutscher Ingenieure."

Many learned men have chosen "compound resistance" of flexion and torsion, as the subject of their investigations; but their explanations have been so elaborate that they have not been read by practical men, and their results have been so complicated, that they will never be applied.

The ordinary process is to calculate



the dimensions of axles first with reference to torsion, and then with reference to deflection; and then, by a sort of *feeling*, to select a diameter larger than the greatest computed. Engineers who are not satisfied with this method generally construct an approximate formula from the cases that come under their observation;

and the various formulas found in their note-books are the best evidence that the requirements of practice in this direction have not yet been satisfied.

The writer had often attempted to construct a simple formula for compound resistance, but had as often been compelled to reject the result. In editing his "Maschinenfabrikation" he took up the formulas most in use with a sort of resignation; but, alarmed by their great number and by the abundance of typographical blunders, he dropped them; the frequent attempt was then repeated and with a perfectly satisfactory result, since the formula deduced is easy and exact in application. Indeed the process is so obvious and natural that it is not easily forgotten.

In the figure the direction of the force P acting on the axle is supposed to be perpendicular to the plane of the paper; let X be the point at which the strain is the greatest. Experience shows that axles subject to both torsion and breaking always break obliquely, as along A B.

Of the sections passing through X it is plain that the breaking section must be that

(1.) Which receives the greatest strain, and in which, consequently, the force P acting with a lever-arm h perpendicular to A B, and acting at Y, is a minimum;

(2.) And which receives at the several points of a line through X, parallel to the force, torsional strains, such that they are in equilibrium with the torsion moment $P \times a$.

Let the breaking modulus for the section $\frac{\pi}{32} D_3 = Q$.

The torsional, $\frac{\pi}{16} D_3 = Q_t = 2\,D$.

r = the absolute lower arm of P.

β = its angle with the axis.

a = the angle of the breaking section with the axis.

$\gamma = \frac{180 - \beta}{2}$.

S = the absolute total strain at X.

Then to satisfy (1) we must have:

$$P h = \frac{\pi}{32} b\, D^2 . S,$$

$$D = b \operatorname{Sin} a.$$

$$h = r \operatorname{Sin} (\beta - a).$$

$$\text{Hence } P = \frac{S \frac{\pi}{32} D_3}{r} \cdot \frac{1}{\operatorname{Sin} a \operatorname{Sin} (\beta - a)}$$

must be a minimum, and consequently

$$Y = \operatorname{Sin} a \operatorname{Sin} (\beta - a)$$

must be a maximum.

Differentiating with reference to a, and making the differential coefficient equal to zero, we have

$$\operatorname{Sin} a \operatorname{Cos} (\beta - a) = \operatorname{Cos} a \operatorname{Sin} (\beta - a)$$

$$\therefore \beta = 2\,a.$$

Substituting, we have

$$P . r \operatorname{Sin}^2 \frac{\beta}{2} = \frac{\pi}{32} D^3 . S.$$

To determine whether condition (2) is satisfied:

The total strain S is composed of a breaking strain

$$S_b = \operatorname{Cos} \gamma$$

and a torsional strain

$$S_t = S \operatorname{Sin} \gamma :$$

Transferring P to Y by supplying two two equal opposite forces, the force P is balanced; since

$$P h \operatorname{Cos} \gamma = Q\, S \operatorname{Cos} \gamma.$$

Half the moment of tension is destroyed by the breaking strain, since

$$P \frac{a}{2} P h \operatorname{Sin} \gamma = Q\, S \operatorname{Sin} \gamma.$$

But since the strain S Sin γ because of torsion acts *round* the axle, it resists a torsion.

$$Q_t\, S \operatorname{Sin} \gamma = 2\, Q\, S \operatorname{Sin} \gamma = P a;$$

that is, the axle is in equilibrium with reference to torsion, and condition (2) is satisfied.

The formula for P may be simplified. Instead of measuring the absolute arm r, the line P Z may be measured. The length of this line is $r = \operatorname{Sin}^2 \frac{\beta}{2}$; and the point Z is found by drawing a perpendicular from D to the line P X. Hence by bisecting the angle β and drawing three lines, the length of P Z is found; putting h for this we have the easy formula

$$P . h_1 = S . Q.$$

Mr. J. L. Booth, Rochester, N. Y., has invented a new rail, which consists of a compound, formed by first rolling the cap and base separately, and then applying them together and passing them together through a rolling or compressing machine, whereby they are firmly united, and without being heated for the purpose.

SUBMARINE TORPEDOES.*

From "The American Artisan."

The Monitor type of war-vessel has proved to be the most formidable, and, so far as invulnerability is concerned, the most perfect; presenting the least surface of exposure to the shot of an antagonist, and therefore being the more readily protected with armor of almost any required thickness. These facts were practically demonstrated during our late war. Since that time other nations, though slowly, are finding out the formidable nature of these vessels, and cannot spend many more millions on their towering broadside vessels before they will be compelled to adopt the Monitor system.

The folly of trying to successfully employ a floating fort has just been demonstrated in the sad loss of the British iron-clad and turreted ship Captain. A heavy lurch in an ordinary storm, and the top-heavy craft went down—a coffin with five hundred souls inclosed!

To John Ericsson belongs the glory of having constructed the most perfect war-vessel afloat, either for offence or defence. A single shot from a 15-inch gun, fired discretionally from any of our later-built monitors, can be made to penetrate with sad havoc some part of any foreign-built vessel-of-war afloat.

With our monitors, our heavy guns will also be imitated—and we must be equal to the emergency arising therefrom. To accomplish this, we may rely, as it is, upon our success above water, but it will be necessary to turn our attention to operations below the surface, and the best means of submarine attack and defence call loudly for attention.

As regards "submarine warfare," we seem yet to be comparatively in the dark, notwithstanding many improvements have been developed in it during the past eight years. Our Government has adopted a system which have worked well in experiment, and which will, no doubt, be very effective in actual practice; but its operation requires close contact with the enemy, and also involves the use of expensive and strong machinery. The object to be attained is the destruction of an enemy with as little danger to ourselves as possible. Water is an element through which we can direct greater masses of explosives than is possible in the air, although at a sacrifice of velocity; 200 or 300 lbs. of powder under a vessel's bottom will unquestionably be more serviceable than the same number of tons of explosives consumed in the ordinary manner above the water-line. The devices through which this result is to be brought about are known as "torpedoes." These will provide the most effective and deadly agencies of the warfare of the future, and, though apparently in their infancy, they have become necessary both in the military and the naval service. The protection of a harbor lies not in its forts (be they manned with the best artillery and men), but in the arrangement of its torpedoes and "infernal machines," placed where the adversary, if he comes, must come to his own destruction.

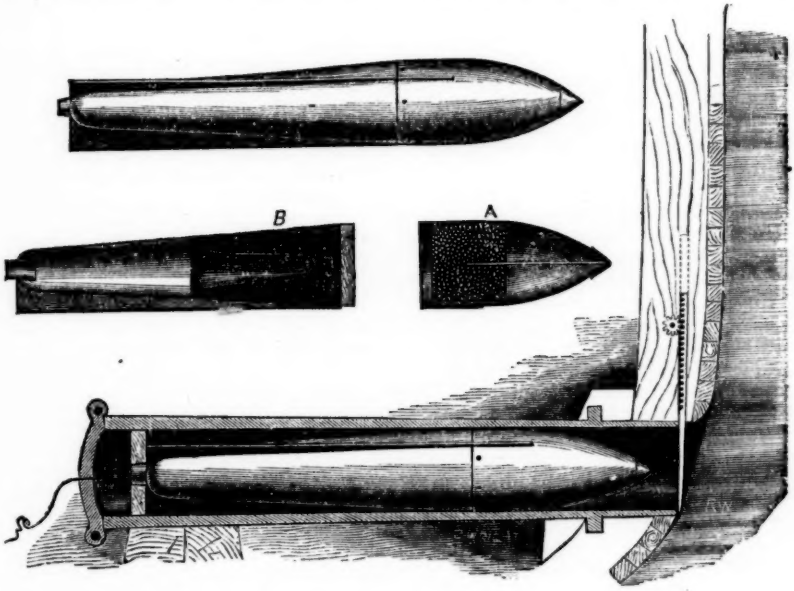
"Torpedoes are supposed to have been first devised by David Bushnell, of Connecticut, about the year 1776. His first use of them was from a submarine boat known as the American Turtle, from its close resemblance to that reptile. With this boat, which could be completely submerged, and which the inventor propelled by an oar, worked as a scull, he would guide himself to the ship which he intended to destroy, screw his torpedo (a tank containing about 150 lbs. of powder) into her bottom; release the catch of the clock-work, which was contained within the powder and connected to a gun-lock trigger, cast off his boat, and return to shore, rising to the surface by forcing, with a pump, the water from his craft. The clock-work was arranged to run a certain time, when the trigger would be released and the charge exploded. Many attempts were made to destroy British vessels with this contrivance, but never with success.

In about 1805, Robert Fulton made similar experiments, but without the assistance of a "turtle;" his success was but little better than Bushnell's. In 1810, he published a work entitled "Torpedo War and Submarine Explosions."

* Abstract of a paper read b fore the New York Society of Practical Engineering, by Robert Wain, C. E.

The next use of torpedoes was in the Crimean war, where the Russians used them to good purpose, not so much in the results of actual explosion as in their demoralizing tendency. In our own late war the rebels employed torpedoes with marked success in many instances. At first, we were inclined to condemn them; but we soon found that we must fight the enemy with his own weapon; and so we became case-hardened from the example of our foemen, and their exertions did more towards the advancement of this branch of military art with us than we could have ever gained without such an unpleasant incentive. A very interesting and instructive work has been compiled by Lieut. Commander I. S. Barnes, U. S. N., in which are given detailed and illustrated descriptions of all the "infernal machines" which were employed against us during the war, and of some of our own inventions to circumvent the enemy.

Since the close of the war, other nations have realized the great importance of this arm, and have taken the deepest interest in its perfection. The Austrians have invented a projectile which, being propelled by compressed air-working propellers, will regulate its depth in the water by a vertical rudder, worked by hydrostatic pressure; the water acting



upon a diaphragm of india-rubber, which will be compressed or expanded according to the depth of immersion. This action is utilized, so that the rudder can be set to retain a certain position for the torpedo, according to the depth the operator may wish to strike an object. We have had rather indefinite descriptions of this torpedo; the few remarks given above were obtained from an army officer who had witnessed a trial with one of those machines.

A British torpedo known as the "Otter," and invented by John Harvey, of the Royal Navy, has been adopted by the Russians, and is considered of great utility in the British navy. This is a wooden casing strengthened with iron, and containing the shell or torpedo within it; the shape is rhomboid, about 1 ft. wide, 12 ft. long, and 8 ft. deep. A cable is attached to this in such a way that when towed from a vessel it can be made to diverge from her course at any angle within 45 deg. To compel this machine to hug the side of an enemy will require a great excess of speed in the assailing vessel, and would be very clumsy

to manage under any circumstances. England prides herself on being now possessed of a machine which is very sailor-like in its action and well suited to the use of seamen, an estimate of the value of the apparatus with which no fault can be found. A number of "Engineering" in March of this year contains an interesting description of a practical test with this torpedo. A steam-tug was used as the towing craft, being fitted with the needful paying-out apparatus, and Capt. Harvey conducted the operations against the iron-clad Royal Sovereign. In the first part of the operation the vessel remained at anchor, and though doing her best to avoid the torpedo, was struck by it every time at depths varying from 1 to 16 ft., the tug towing the torpedo with about 50 fathoms of line. In the next trial the Royal Sovereign got under way, steaming about 8 knots, the tug making about 11 knots, and in the six trials made every torpedo struck and the caps were exploded.

John Ericsson has brought up some later ideas in regard to submarine warfare, which are worthy of much consideration. One proposition is that the torpedo shall be driven by two propellers working in opposite directions; the shaft of the outward propeller revolving inside the other. The motion given to these shafts would be through rotary engines, driven by air supplied from the ship through a flexible tube which is towed out from the vessel's side as the pressure works the propellers. The torpedo will be guided by a greater or diminished allowance of air as the tube is reeled off. This is practicable, but the necessary connections of the apparatus are cumbersome and liable to derangement. Mr. Ericsson's last proposition is to throw elongated shells from 15-inch guns at moderate ranges, letting them dip into the water before reaching the vessel aimed at, and continuing their course to strike the enemy several feet below the water-line and explode. These shells are to contain 200 lbs. or more of dynamite, and their range would be about 1,500 ft. If this is practicable, we only need gunners with thoroughly practised and educated eyes to calculate their distances to a nicety. The details of slow-burning charges and safety in the use of dynamite are expected to be solved, as also the proper direction of the axis of the shell.

In 1864 I was attached to one of the vessels of our wooden blockading fleet off Mobile Bay, and was sent from there to Pensacola to construct some torpedoes to be used from the bows of our ships—a temporary arrangement, which was invented from the necessity of the hour, our fleet being constantly exposed to attack from formidable rebel iron-clads. It was here that I made my first experiment with a projectile, the principle of which, and the experiments carried on with the apparatus, I now propose to describe.

This torpedo is really a submarine rocket, a slow-burning powder being used to supply the propelling power, while the construction may be justly characterized as plain and simple, the device being composed of only two parts, viz.: the exploding shell, or torpedo proper, and the rocket, or propelling shaft. Both parts can be made of copper, zinc, sheet-steel, or thin boiler-iron. In the engraving A is the torpedo, or exploding part of the projectile. This is shaped like an ordinary rifle-shell, to present a surface of least resistance to the water. The apex, when the apparatus is in use, consists of an easily ignited percussion fulminate, covered with a thin or film-like coat of copper, covering several inches of the point of the shell, so that contact with any part of the front will ignite the charge. The shell is then filled with the exploding powder through a hole in its base. B is the rocket, or shaft-projector—a hollow, tapering shaft made of thin, strong material, to be filled with slow-burning powder. On the outside, and at equal distances apart, are three wings or keels, set on the same line as the axis of the projectile. The small end of the shaft has a contracted opening, through which the gas of the rocket-powder in the chamber is to act in propelling the torpedo. This shaft is loaded with a large rocket, or the rocket-powder is rammed into it, as in a rocket case, leaving a central opening, of large surface, for the burning powder, which is mixed with a greater proportion of sulphur to insure the necessary action.

When filled, the large end is securely stopped with a carefully-fitted plug or

sabot of wood, and it is then set into the lower rim of the shell, where it fits snugly. It can be secured in this position by screws, which join all parts together with strength. The weapon is now ready for use; and, as it must be projected from below the surface of the water, a gun or guide of sufficient strength, and of simple construction, can be secured in the vessel's side or bows 8 or 10 ft. below the water line, as needed. This will have an outboard and inboard, or breech valve. To load, the outboard valve will be closed, and the inboard opened; the torpedo will be carefully run into the chamber to a marked distance. A thick, wooden sabot, with a hole turned in the centre of it, just large enough to receive the projecting tube of the shaft, is then placed against the swell and wings of the instrument, fitting snugly in the bore of the gun, as will be seen by the drawing, and leaving a space of several inches between itself and the inboard valve. A friction primer is now set in the tube connecting with the slow-burning powder; the wire from this runs through the inboard valve, which is now closed, and the outboard valve is opened, admitting the water freely around the torpedo to the sabot. The instrument is now ready for use. Possibly, it may be necessary to assist so large a body in starting. This can be done by mechanical means. After firing, which is directed from deck, the outboard valve is closed, and the inboard valve opened, allowing the water from the gun to run into the hold of the ship. Another torpedo is placed in position, etc. This operation of loading and firing will consume no more time than has been occupied in its description. The torpedoes being made, and cased ready for use, are stored in the magazine like loaded shells.

Any vessel can be armed with these torpedoes, for the construction of the gun or guide is comparatively simple; the power which forces the projectile from the gun, being contained in itself, will necessitate but little trouble in handling. One of our monitors, armed with three or four of these guns, could defy the navies of the world. In the very first experiment that was made to test this principle, its success was made apparent. The torpedo was constructed of light pine wood, turned to the shape of a spindle, 25 in. in length, and 3 in. in diameter at the centre, and, being composed of two pieces, was cut away in the inside to admit of ballast and an ordinary government rocket. It was then carefully weighted with lead, making the specific gravity very little more than that of water, so that when it was placed in the water it would slowly settle to the bottom, and still retain a horizontal position. The after or rear part of the spindle was provided with three wings of tin, placed equidistant from each other, and in a true line with the axis of the spindle. It was fired from a wooden-box guide at a depth of 2 ft. below the surface of the water, and where there was but little tide or current, at a target placed 63 ft. distant. The torpedo started almost instantly from its position of rest, and travelled most satisfactorily, making about 12 ft. a second, as it took five seconds to accomplish the distance, striking the target 3 ft. to the left of the centre, and 2 ft. 10 in. below the surface of the water. This excess in depth was attributable to the lightening of the after-part of the spindle by the burning away of the rocket powder, causing that part to lift.

This experiment was followed by numerous others, all of which clearly demonstrated the success of the principle. These projectiles could be used at any distance under 250 yards with effect. A little practice with that short range would enable the operator to be pretty sure of hitting his mark. And for attack against a fleet entering a harbor or otherwise, the range could be unlimited, as the propelling powder is made to last. With this arrangement, a man need not be hoisted by his own petard, as is so apt to be the case where close contact of the operator is required.

It will be seen that the velocity of these projectiles will depend upon their shape and sectional area, as well as the powerful action of the generated gas. They must be well and carefully proportioned, their length being not less than six times the diameter. Torpedoes, for the use of ships, could be made about 18 or 20 in. in diameter, containing from 175 to 200 lbs. of explosive powder; and, for harbor defence, they might be made 2 ft. in diameter. One of this latter diameter would be 12 ft. long, and, being made of scant ¼-in. boiler iron, the weight of the entire shell would not exceed 600 lbs.

The displacement of water would be nearly 20 cubic ft., or 1,234 lbs., leaving 634 lbs. for the explosive and propelling powders. 300 lbs. could be used for the generation of the gas, and 340 lbs. for the exploder; but, for harbor defence, nitroglycerine could be used, and thereby reduce the size of the torpedo considerably; and by reducing the size of the shell, and lengthening the shaft proportionat ly, such a mixture could be used as would generate a tremendous pressure of gas for the propelling force, and, by reducing the time of travel to a minimum, insure better results. In some of the experiments which were tried, the velocity attained by this means was astonishing. The projectiles were made of tin, and about 10 diameters in length, with carefully pointed heads of wood—the whole length being 3 ft., and propelled by 20-oz. rockets. They looked like living fish under the water, darting in a true line with as great velocity. To perfect this arm, experiments must be tried on a large scale; possibly they might be made considerably heavier than water and used on the principle of rockets, that is, to start them with an elevation approaching the surface of the water midway in their course to the enemy, and, gradually sinking towards the end of their course, strike and explode.

Their use can certainly involve but little detail in the construction of the guns or guides, for, when the torpedo is ready to be fired, it is no more weighty than water; and to start it, compressed air could be admitted behind the sabot at the moment of firing. This sabot in starting becomes a piston, which receives nearly all the starting pressure. It keeps the water from contact with the gases in the gun, which would otherwise be partly reduced or condensed; and, on compressed air being suddenly admitted, the powder will burn freely, and the inertia of the mass be gradually and delicately overcome. As the sabot leaves the mouth of the gun, it meets water at rest, and the onward motion of the torpedo frees it, when it is free to rise to the surface. The delicate cap on the end of the torpedo will cause the explosion if it strikes at any angle outside of about 30 deg. from its own line of course, so that the enemy may be struck in any position. It is within bounds to say that these torpedoes could be made to travel 36 ft. a second, or at the rate of 25 miles an hour. In this case, if an enemy is 250 yards distant, it would require about 20 seconds to reach her. This tardiness will certainly require some dead reckoning on the part of the operator; but practice will soon give him complete control of the machines, so that, whatever may be the intervening tides or currents, or the swift motion of the enemy's vessels, he would be able to strike home, say 9 times in 10. 300 lbs. of composition, requiring half a minute to consume, would give all the power required for propulsion. However, as I have before stated, the real value of this principle can only be arrived at by practice on a large scale. There might be some minor details to be regulated with reference to the proper regulation of the composition used, generating the propelling gases, but any difficulty in this respect can be easily overcome. In conclusion, I see no reason why every vessel in our navy could not be supplied with this arm in addition to their present batteries, and thereby be enabled to defy all comers. For harbor defence, these torpedoes would do away with the use of forts, for small floating batteries could be anchored at intervals across the entrance. These could be made invulnerable above and below water, and each armed with several of these guns, and, furnished with the calcium light for night work, would render a seaport impregnable.

A very curious influence exerted by heat upon diamonds has been noticed at the works of St. Helen's, recently visited by the British Association. When a diamond is used to cut hot glass the diamond will only last for one day, and it assumes a milky appearance. The diamonds in constant use for cutting cold glass last about three months. Each diamond costs from 35s. to 45s., and is about three times the size of an ordinary glazier's diamond. Hot glass is cut more readily than cold glass.—*Popular Science Review.*

The "Moniteur" comments severely upon the undisturbed Prussian railway communication between Paris and Saverne, and recommends the formation of bodies of men specially charged to destroy the German communications.

LOCOMOTIVE IMPROVEMENT.

From "The Engineer."

Every competent engineer, civil or mechanical, will admit that the locomotive engine, approximately perfect as it is, may yet be rendered better. The civil engineer, indeed, demands that it may be made less damaging to his roads, while the locomotive superintendent earnestly desires to effect a saving in fuel and in the cost of repairs. If then it is admitted by both classes of the profession that improvement is desirable, how is it that the improvement is not effected? It cannot be because constructive skill is lacking. The absence of ingenuity cannot be pleaded as an excuse. The true answer is, that the locomotive is daily undergoing small, almost imperceptible, improvements on the one hand, and, on the other, it must be borne in mind that the locomotive is so nearly perfect in its best form, that the task of making it still better without launching out into a course of costly experiments, for which railway companies have no available funds, is extremely difficult of performance. To use an often quoted illustration of the late Dr. Lardner's, imperfections which will ruin a razor are of no account in a carving knife. It would not be very difficult to make an average carving knife of good steel as sharp as a razor, but it would be impossible to make any razor as much sharper than the average of razors. If the locomotive were not very good indeed it would be easy to make it better; in the fact that it is very good lies the obstacle in the way of further perfection. It is by no means to be assumed, however, that the obstacle is insurmountable. What can be done in the way of effecting economy of fuel in one engine, men ought to be able to do in another. If we can get a horse power for the consumption of 1.5 lb. of coal in the case of the marine engine, we ought to do nearly as well in the case of the locomotive. Certain engineers have shown that it is possible to haul enormous loads without so seriously weighting the driving wheels as to compromise the stability of permanent way. All locomotive designers ought to be able to do the same. If they are competent men, and do not do this, then we must assume that some good reasons exist for the fact. Let us see what these reasons may possibly be; and let us also consider for a moment the direction in which the improvement of the locomotive is most likely to be effected and is most desirable.

The subject may be best dealt with under three heads: Firstly, the locomotive as a steam generator; secondly, the locomotive as a steam user; and thirdly, the locomotive as a vehicle. It is with the last alone that the civil engineer has, strictly speaking, anything to do. It is only as a vehicle that the locomotive destroys permanent way. The question of what it will draw, and the relation which its power of drawing bears to the contour of a line, troubles him but little in determining that contour, because he knows that whatever that contour may be, the mechanical engineer is prepared to supply him with engines to work it with regularity and efficiency.

The first question, then, for consideration is the improvement of the locomotive as a steam generator; and with this alone we shall deal at present; to the others we shall refer at no distant date. There is no room to doubt that the very best locomotives are uneconomical steam generators. The rate of evaporation seldom exceeds 7 lbs. of water to one of coal. In exceptional instances 8 lbs. or even 9 lbs. have been evaporated, or a little more perhaps; but in these cases the boilers have been new, and the surfaces free from deposit. It is unfortunately a condition of the locomotive boiler that the tubes cannot be freed from scale without taking them out; and as it is certain that scale accumulates more or less slowly according to the quality of the water and the care exercised by the drivers, but does still accumulate, the evaporative economical efficiency of every locomotive must fall off year by year, and decrease from what it was at first. Bearing this in mind, it will not, we think, be wrong to assume that the average duty of all the locomotives in England will not greatly, if at all, exceed 6.75 lbs. of water fairly evaporated — not primed — into steam. But this is, as we know, far below the efficiency of other types of boiler. It should not be too much to expect an

evaporation of 8.5 lbs. of water per pound of coal, considering how good the coal is that locomotives usually burn, and the skill of the stokers who attend to its consumption. Is it or is it not possible to obtain this result, not in exceptional cases, but in thousands of locomotives, year after year, and in all parts of the United Kingdom? We fear that the answer must be in the negative. If the past teaches any lesson worthy of notice, we are certain that it cannot be effected so long as the existing type of boiler is retained in its absolute integrity. The horizontal tubular, or locomotive boiler, has undergone an enormous number of modifications, but not one real improvement has been effected. The most highly approved locomotive boiler of the present day is identical with those in use in 1840 in every respect save its dimensions, the quality of its workmanship, and a brick arch in the fire-box. Long grates, combustion chambers, and in the best practice mid-feathers, have disappeared from the railway world. We have nothing left but the approximately cubical fire-box, and a greater or smaller number of brass or iron tubes of a greater or lesser length according to circumstances, running straight to the smoke-box through a cylindrical shell. Not one of the innovations on George Stephenson's designs appears to have obtained any substantial footing in modern locomotive practice. We are, on these grounds, justified in stating that, so long as the modern locomotive boiler is retained, nothing whatever is to be expected in the way of securing a greater economical evaporative efficiency from the fuel used.

The question naturally suggests itself, is it essential that we should continue the use of a boiler admittedly not the most economical? It is not easy to reply to this question. On the one hand, it may be urged that it is possible to work locomotive engines with boilers very different indeed in form; while, on the other, we have the practice of the last thirty years, and of the best mechanical engineers who have perhaps ever lived, in favor of the existing boiler. It is, besides, very difficult to design any other boiler which will comply with the requisite conditions. Where else is there a boiler to be found which will supply us with as much heating surface within a given space? Where is there to be found a boiler at once so easy to make, repair, and keep in order, so safe, so strong, and, all things considered, so cheap? Where is the boiler which admits of such an efficient distribution of weight, is so good-looking—and even good looks are worth considering in designing a locomotive—presents so large an area of water surface—essential to the production of dry steam—and is so easy to fire and attend to in every way? We may answer at once that there is not one in existence. But granting this, it must not be forgotten that it may be possible to design boilers which, differing more or less widely in important respects from the existing boiler, and sacrificing certain of its merits, will nevertheless be better in this, that they will prove more economical as far as the consumption of fuel is concerned. Whether such boilers can or cannot be produced remains to be seen; but it is at all events certain that no locomotive engineer can prove that it is impossible to build a very efficient locomotive with, for example, a vertical boiler. Such a boiler would of necessity be as unlike the ordinary locomotive boiler as possible—and it is for that reason we cite it to illustrate our meaning—but this does not prevent its application to the required purpose. The distribution of weight could be effected with ease; the qualities of the locomotive as either a steam user or a vehicle would remain unaffected; the convenience of firing would be the same as now, cost and weight would remain unaltered. Only two really effective arguments can be brought against a vertical locomotive boiler. The first is, that it is impossible to provide sufficient heating surface of the kind in any suitable vertical boiler; the second is, that a locomotive with a vertical boiler is opposed to all preconceived notions on the subject of locomotive engines. To which we reply, first, that it is by no means certain that a boiler of the vertical type cannot be devised which will contain as much heating surface, within a shell of given size, as any locomotive boiler; and, secondly, that the mere fact that no other boiler than the existing type has been used hitherto in first-class locomotives is no reason whatever why it should be adhered to till the end of time. The question, in short, narrows itself to this, is it or is it not desirable that every

pound of coal we burn in a locomotive should or should not make more steam than it does? The universal reply will be that it is highly desirable that the utmost possible value should be got out of the coal purchased by railway companies. But it is certain that nothing further is to be expected in this way from the existing locomotive boiler. The best men of the day have worked at it since 1840; that is to say, for thirty years; it is as perfect now as it is possible it can be, and yet it is inferior in evaporative efficiency to a host of other boilers. To assert that any further improvement is to be expected is simply to assert that Mr. Ramsbottom, Mr. Beattie, Mr. Cudworth, Mr. Miller, Mr. Johnson, Mr. Sinclair, Mr. Sturrock, Mr. Martley, Mr. Adams, and hundreds of other engineers both in this country, France, Germany, America, etc., really do not know their business. Under the circumstances, we are justified in repeating the assertion that if more steam is to be made per lb. of coal burned we must alter the type of boiler.

It will, no doubt, be urged by certain of our readers that this is a most "unpractical" article. We grant that it is unpractical in the sense that it indicates, under certain conditions, the necessity for innovations in ordinary locomotive practice; but we cannot admit that it is unpractical in any other sense. No one who is well up in his subject, can deny that further improvement in the evaporative efficiency of the existing boiler is a thing not to be expected in the face of modern practice, which is reverting as fast as possible to the oldest and simplest type of boiler, as may be proved by an inspection of the latest engines on the Midland, Great Eastern, London, Chatham, and Dover, Great Northern, Great Western, North London, and many other railways. At the same time greater exertions than ever are being made by locomotive superintendents to cut down coal bills. The question we submit is, not whether it is right and proper for a journal like this to suggest innovations on existing practice, but whether these changes so suggested are or are not likely to secure the desired end, and comply at the same time with the required conditions. And we desire it to be especially borne in mind that in this article we have done nothing more than enforce on our readers the *fact* that no improvement can be expected in the existing locomotive boiler, while we place before them the *suggestion* that a different type of boiler might be designed—if it be not designed already—which would prove more economical in the consumption of fuel, and equally convenient for locomotive purposes. We shall not so far wrong locomotive superintendents as to believe that they are so wedded to their own practice that they can see nothing worth consideration in the idea of others, although these ideas may introduce somewhat novel views on the future of the locomotive engine. We do not put it forward as certain that a different type of boiler would be better than the existing type, but we think it probable; and it is indisputable that designers of locomotives generally should not be deterred from introducing possible improvements simply because they are essentially different from existing practice.

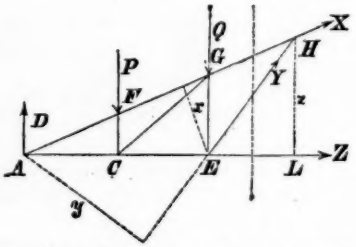
A process for the colorimetric estimation of gold in quartz has been submitted by Mr. Skey, of the Government Laboratory, to the Philosophical Society of Wellington, New Zealand; it is stated fully to meet all requirements, and it does not necessitate the use of quicksilver. The stone to be estimated, after having been thoroughly crushed and calcined, is immersed in a bath of iodine or bromine, and permitted to stand for some time. Slips of Swedish filtering paper are then alternately dipped into the fluid and dried, until the paper is thoroughly saturated with the fluid, after which they are burned in a muffle. If no gold be present the ashes will be white; but 1 dwt. to the ton will give them a beautiful purple color. It is believed that further experiments with odine or bromine baths of known contents of gold will enable the exact proportion of gold to be tested by the colorimetric method.

A Prussian decree has been issued, ordering railway companies immediately to take measures to accelerate the transport of troops and war material. One hour will be allowed for changing from one line to another, and two hours for changing to another company's line. A certain number of telegraphists is to be attached to each army corps.

CALCULATION OF STRAINS IN TRUSSES.

August Ritter, in his Dach-und Brücken-Construction, determines the strains in a roof or bridge truss by applying the principle of static movements. The method is sufficient for finding the strains in ordinary trusses, in lattice, bow-string, and parabolic girders, and in suspension bridges; it is also applicable in the determination of maximum and minimum strains.

FIG. 1.



The general rule may be expressed as follows:

Conceive the construction divided by a section, cutting off only three pieces if possible; and consider the forces X, Y, Z, representing the strains in the several pieces as applied at their intersections.

To determine X, take moments about the intersection of Y and Z; to determine Y, take moments about the intersection of Z and X; for Z, take moments about the intersection of X and Y.

The reactions at the points of support, and the distributed loads at the several points of support, are to be found by the ordinary methods.

Applying this method to the diagram: To find X, take moments about E, giving

$$X\,x - P.CE + D.AE = 0$$

$$X = \frac{P.CE - D.AE}{x}$$

To find Y, take moments about A, the intersection of X and Z.

$$-Y\,y + P.AC + Q.AE = 0$$

$$Y = \frac{P.AC + Q.AE}{y}$$

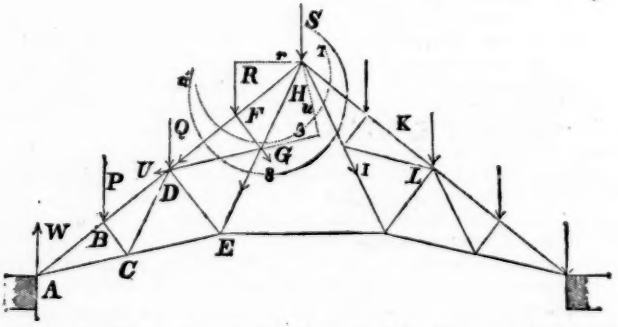
To find Z, H is taken as the centre of moments;

$$-Z\,z - Q.EL - P.CL + D.AL = 0$$

$$Z = \frac{-Q.EL - P.CL + D.AL}{z}$$

This method is adequate in all cases in which the section does not cut off more than three pieces.

FIG. 2.



In complex trusses, as, for example, in Fig. 2, it may happen that there are pieces (F G, D G, D E) which cannot be cut off in this way. In such a case the desired result can be directly obtained, if a section, either rectilinear or curved, can be passed so as to intersect all the pieces that meet at one point.

The strain in V, for example, can be found by passing the section $\alpha\,\beta\,\gamma$ through four pieces and taking moments about H; giving

$$-V.FH - R\,r = 0$$

$$V = -\frac{R\,r}{FH}$$

The strain U in the piece D G, there-

fore, is found by passing the section $a\,\delta\,\gamma$; giving

$$U\,u - R\,r = 0.$$

$$U = \frac{R\,r}{u}$$

The strains in opposite corresponding parts may be found in the same manner. The strains in the remaining pieces may be found by similar sections, or by sections passing through four pieces, one of which has already been determined.

For example, when U is known, we find for R, S and T, the strains in D F, D E, and C E.

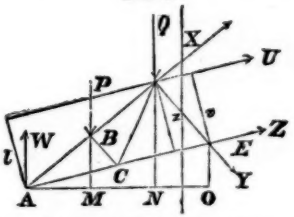
X.D E + U v − Q.N O − P.M O + W.A O = 0 (centre at E).

Y.A D + U l + Q.A N + P.A M = 0 (centre t A).

− Z z + W.A N − P M a = 0 (centre at D).

The advantages of this method hold as well for more complex structures. At first, calculations may be made with the aid of detached diagrams representing

FIG. 3.



the several forces that enter the equation of equilibrium. After a little practice this will be found unnecessary.

Applications of this method will be be given in future numbers.

HISTORY OF THE IRON RAILS UPON THE MICHIGAN, SOUTHERN AND NORTHERN INDIANA RAILWAY.*

About 330 miles of this line were laid down in the year 1851, and operated immediately thereafter with a considerable traffic; but, the Company being then engaged in the construction of branch lines, no accurate account of expenses or renewals was kept until the branches were finished, in 1857, when the length of track owned by the Company, including sidings, was 567 miles.

I have included sidings in the length of track and in all calculations of the averages of wear, because, taking into account the excessive service at the termini and principal stations, the sidings will require as much iron for renewals as an equal length of main line.

The gradients and curves upon this road are light, the maximum gradient 28 ft. per mile, and the sharpest curves of about 1,900 ft. radius, excepting a few short planes and curves upon the branch lines, which are more severe.

The iron rails first laid upon the road were nearly all of British manufacture, of 56 and 57 lbs. per yard, "Erie pattern," with a pear-shaped head, 3½ in. high and 4 in. base; about 50 miles, of similar section, from Brady's Bend, Pa., which proved dangerously brittle, having been the only American rails now known to have been laid in the first track. The British rails were made from piles apparently composed of only one kind of iron, presenting an even, granular fracture throughout the section, and were much better welded than any made in England or in America, which we have since procured to replace them. They were 15, 18 and 21 ft. long—chiefly 18 ft; partly laid with cast iron and partly with wrought iron chairs; the joints opposite, and resting upon a single tie. The sleepers were mostly of white oak, laid 2½ ft. apart centres; 8 ft. long, 6 in. thick, and from 6 to 9 in. wide. The ballast was of sand, or very fine gravel; but the road bed was not thoroughly ballasted—in parts, not at all.

As would be expected from these conditions, the rails were rapidly bruised at the ends; so that as early as 1856 those laid previous to 1852 were in desperate need of repairs, and a force of smiths was in that year set at work mending them; by which means a large proportion of the rails, which had to be removed because of their bruised ends, were restored to the track. The condition of the main line was also helped, by taking the sound railings from the sidings and branches, and

* From a paper read before the Am. Society of Civil Engineers, by CHAS. PAINE, C. E.; with remarks on the construction and wear of rails, by J. DUTTON STEELE, C. E.

replacing them with battered or mended rails, so that the necessity for the purchase of new rails for repairs was postponed.

Since 1859, the surface of the track has been maintained in excellent condition, and the road has been in as good order, in respect to depth of ballast, drainage, and prompt renewal of sleepers as any of the best lines in the United States; so that rails have had a fair chance to show good results in wear, if the nature of the metal from which they were made and the mode of its manufacture would permit. It would have been better for the track and for the rolling stock, if repairs had begun sooner, and if they had been more liberal in amount, at first; for the tables given here, which show what was done by way of repairs, do not fully indicate what ought to have been done, but only what it was possible to get along with.

A considerable and judicious economy was effected by the mending of rails, instead of re-rolling them, since the cost of re-rolling has averaged, during the period included in this account, about $3,500 per mile, while the cost of repairing rails by hand has averaged about $600 per mile; the mended rail not being so good, of course, as the re-rolled rail, but serving the purpose of keeping the track in a condition of comparative smoothness.

On a part of the main line, 18 miles in length, which had already been re-laid with mended iron, where the grades were very light and few curves, it was found that the mended rails averaged a wear of twenty months before being taken up to be again repaired; on branches, they wore longer.

The metal laid down in renewing the track, except about 30 miles of British iron, has been chiefly re-rolled rails of 61 lbs. weight per yard, with a pear-shaped head; 4 in. high and 4 in. wide on the base. About 50 miles were laid with fished joints, for which the section is of improper shape, and which, of course, did not do well; the remainder was laid with a modification of the "*Howe joint.*" This joint has proved the best of any, upon a light, sandy ballast, the only material which was available upon this line, and one which requires that the joint should have the broadest and steadiest bearing upon it which can be devised. Reports of the condition of all the rails removed from the track, show that where the plate chair upon a single tie is in use, $\frac{64}{1000}$ of the whole number are bruised at the ends only; whereas, upon the portions of the line where the Howe joint is laid $\frac{29}{1000}$ of the whole are so bruised. Since 1858 the centres of the sleepers have been laid 2 ft. apart; since 1864 the sleepers have been 9 ft. long.

It will be observed in the tables that the rails of 1864 and 1865 proved exceptionally bad. Previous to 1864, the rails had been re-rolled in "two high" rolls, from solid piles of from 6½ to 7½ in. square (sometimes composed entirely of re-worked rails, sometimes with a head-flat of harder metal), into rails 21 ft. long. At this period, the enormous cost of iron, owing to the rebellion and to the tariff, caused railway managers to seek for the cheapest quality which could be obtained; and although re-rolled rails were then evidently inferior to the rails first laid down, and were wearing out with alarming rapidity, resort was had to "three high rolls," and to piles from 9 to 10 in. square, in which were from 3 to 6 pieces of old rails which had not been broken down into flats; and these piles were rolled out into rails 27 ft. long. This mode of manufacture continued until near the close of 1867; by returning then to solid piles—in some reducing them in size, and by the use of raw puddle-bar between the harder head-flat and the re-worked old rails—better welding has been secured, and the resulting wear has been much prolonged; yet these rails are not equal in quality to those made from 1860 to 1863. The length adopted for rails after 1865 was 24 ft. Since this time, it has been found that the larger the proportion of new metal introduced into the piles, the better have been the rails—a result probably due to the fact that a great part of the rails which were being re-rolled, having been re-worked once or twice before, had become quite unfit for making rails again. Although this experience of 1864–5 was convincing that the solid pile is better than one composed in part of old rails, not broken down, yet, as many rail makers and some engineers still maintained a contrary opinion, an experiment was afterwards made to settle the question. A lot, some hundreds of tons, of rails was made from piles in which there were three unworked pieces

of old rails; and another lot was made from the same iron and according to the same specifications, at the same mill with the first lot, with only the difference that all the old rails used were first broken down into flats. These two lots of rails were laid down in situations where they would undergo similar wear, and at the end of one year the two classes were compared; of those made with old rails in the pile, $\frac{1}{12}$ had been removed from the track, and many others were showing signs of disintegration; of the rails made from the solid piles, $\frac{1}{24}$ of the whole had been removed, and the remainder were apparently in good condition.

TABLE No. 1.

NEW AND REPAIRED RAILS LAID DOWN UPON THE WHOLE ROAD.

Year.	Miles of Road Operated.	Miles of New Rails Laid Down.		Miles of Rails Repaired.		Miles of New and Repaired Rails Laid Down.		Average Number of Trains Over each Mile in the Year.
		In Year.	Total.	In Year.	Total.	In Year.	Total.	
1852.	330	....	.....	....	....	....	....	3580
1853.	334	....	.....	....	....	....	....	4180
1854.	340	....	.....	....	....	....	....	4620
1855.	340	....	.....	....	....	....	....	4950
1856.	343	....	.....	30	30	30	30	4670
1857.	567	....	.....	65	95	65	95	3280
1858.	574	....	....	86	181	86	181	2710
1859.	574	6.96	.....	84	265	91	272	2650
1860.	574	8 62	15.58	79	344	88	360	2780
1861.	574	10 18	25.76	80	424	90	450	3100
1862.	574	20 87	46.63	95	519	116	566	3600
1863.	574	23.56	70 19	86	605	110	676	3790
1864.	570	39.05	109 24	97	702	136	812	3840
1865.	575	46.18	155 42	94	796	140	952	3800
1866.	578	91.03	246.45	81	877	172	1124	4130
1867.	583	66.30	312 75	122	999	188	1312	4110
1868.	587	87.33	400.08	138	1137	225	1537	4570
1869.	596	94.85	494.98	73	1210	168	1705	5000

NOTE.—The length of main track maintained after 1856 was 524 miles: the subtraction of this sum from the numbers in the column of miles operated will give the length of the sidelings.

Jan. 1, 1870.—There remained on the branches 120 miles of the iron laid in 1856-7, all of which had been repaired.

The great increase in miles repaired in 1867 and 1868 is due to the increased length of the rails repaired.

In 1864 the use of a branch, four miles long, was suspended.

TABLE No. 2.

TRAFFIC BORNE BY THE NEW RAILS LAID DOWN UPON THE WHOLE ROAD.

Year Jan. 1 to Dec. 31.	Miles of Rails Laid Down.	Miles of same Rails Remaining in Track Jan. 1, 1870.	Per cent. Remaining.	Per cent. Worn Out.	Average Number of Trains over each Mile in the Year.	Average Number of Trains which have Passed over Rails Remaining Jan. 1, 1870.
1859.	6.96	1.22	17.5	82.5	3300	50,000
1860.	8 62	3.52	40.8	59.2	3480	46,500
1861.	10.18	4 65	45.6	54.4	3880	43,000
1862.	20.87	6.25	29.9	70.1	4500	38,500
1863.	23.56	9.34	39.6	60.4	4740	34,000
1864.	39 05	10 86	27.8	72.2	4800	29,500
1865.	46.18	23.12	50 0	50.0	4800	24,500
1866.	91.03	76.30	83.8	16.2	5160	19,500
1867.	66.30	59.70	90.0	10.0	5140	14,500
1868.	87.33	86.63	99.2	0.8	5710	8,900
1869.	94.85	All	....	....	6100	.....

This Table is calculated upon the assumption that upon one-third of the whole length of the line, where very little new iron has been laid, only one-half the average traffic is experienced This assumption is very nearly correct, and rejecting the service upon this one-third of the line from the calculation of averages, the above results are obtained.

TABLE No. 3.

TRAFFIC BORNE BY THE NEW RAILS LAID DOWN UPON THE WESTERN DIVISION.

Year Jan. 1 to Dec. 31.	Miles of Rails Laid Down.	Miles of same Rails Remaining in Track Jan. 1, 1870.	Per cent. Remaining.	Per cent. Worn Out.	Average Number of Trains over each Mile in the Year.	Average Number of Trains which have Passed Over Rails Remaining Jan 1, 1870.
1859.		None.	..	..	5396	.....
1860.	2.91	0.58	18	82	5350	72,000
1861.	3.17	3.13	39	61	6170	66,000
1862.	8.03	1.57	12	88	7260	59,500
1863.	13.12	4.51	30	70	8020	52,500
1864.	14 78	3.44	13	87	7530	44,500
1865.	26.14	0.62	4	96	7470	37,000
1866.	15.68	9.02	42	58	7910	29,500
1867.	21.46	25.19	80	20	7910	21,500
1868.	28.74	23.32	99	1	8890	13,500
1869.	23.46	28.79	100	..	9000	.....
	28.79					

Upon this division, as upon the whole road, the traffic has been proportioned as follows:

Freight trains	0.5
Passenger trains	0.4
Working trains	0.1
	1.0

The above tables have been compiled from the annual reports and from the records of the Engineer's department. Excepting the first two or three years of the existence of the Railway Company, accurate accounts have been kept of the miles run each year, by the engines, including switching engines. For those years, the miles run by engines have been calculated from the traffic returns; from this account of the total number of miles run by engines has been deduced the average number of trains over each mile of the track, dividing the total miles run by the total number of miles of road operated, including sidings. Upon the western division of the road, which is about 100 miles long, and the most severely worked of any part of the line, the miles run by engines have been recorded separately from the accounts of the other divisions; and as the traffic over this division is very uniform throughout its length, Table No. 3, which shows the experience of 10 years upon it, is a very correct exhibit of the performance of re-rolled rails.

In considering these tables it should be remembered, as indeed Table No. 1 clearly reveals, that the life of all the iron has been prolonged to its farthest limit by repairing; this was more practicable with the first rails laid down than it is with modern ones; because, although from the imperfection of the joint used, they became battered at the ends, they remained sound in the middle, being more thoroughly welded. The rails now made are laid upon an improved joint; if they fail anywhere it reveals bad manufacture, and the imperfect welding generally extends throughout the length of the rail, rendering it useless to repair it—so that only about one-half the number of rails formerly repaired in each year are now mended, although by improved machinery it can be done at less cost, and better.

I am aware that this account of an experience with iron rails will not have the interest which it would have possessed before steel rails were so generally adopted for the renewals upon heavily worked lines; yet, even now, there are engineers who need to be reinforced in their struggle against mistaken views of economy, and to these I offer this contribution, as *Memoires pour servir*.

The length of main track maintained after 1856 was 524 miles, the subtraction of this sum from the numbers in the column of "miles operated" will give the length of the sidings.

REMARKS BY J. DUTTON STEELE, CIVIL ENGINEER, MEMBER OF THE SOCIETY.

Referring to the paper which has just been read on the wear of rails, etc., there is no doubt but it is a correct exposition

of the experience on the road referred to, and as such is of value ; but so various are the influences, both from the modes of manufacture and the local peculiarities to which rails are subjected, that statistics from other roads may be provided showing directly opposite results in several important particulars.

We have, in this paper, the principle strongly implied, if not directly expressed, that iron may become so highly refined by repeated workings, that it cannot be welded without the interposition of less pure layers—a popular theory among rail makers, but one which I apprehend is entirely in error. Indeed, I have heard this mode of making rails characterized as not welding their parts, but sticking them together with cinder. The best iron we have is made from scraps ; we hear nothing of the difficulty of welding them, no matter how often they have been worked ; the more worked the better. The celebrated Damascus blades, the highest quality of carbonized iron of which we have any knowledge, is said to be made of wire ; and the same principle is acknowledged in our country, where wire ropes are much used. When superior iron is needed it is made from worn-out wire ropes ; though more care is required to weld pure than impure iron, particularly where it is worked in large masses. Those who were connected with the early railroad experience in this country have a pleasant recollection of the double refined Eba-Vale rails, which were among our first importations. Unfortunately for the rail interest, when worn out as rails they were too valuable for re-conversion, and found their way into car-axles and other similar uses. The manufacturers of these higher qualities of iron found no difficulty in welding them, though the rail makers would sandwich them with their own poor stuff, if they were allowed to do so.

In a somewhat extended experience upon one of the largest freight roads in this country, it was my practice, for many years, to have the old rails reconverted, without any admixture of new iron ; the best rails, such as the Eba-Vale, were selected for the heads, and the inferior for the flanges ; all were broken down into slabs and thoroughly welded ; and, to secure as perfect a weld as possible, an English mode of effecting the same object was adopted, that of taking upon the rail piles two welding heats, by passing them several times through the rolls, after the first heat, and returning them to the furnace before they were finally drawn into rails. The result was better rails than were obtained by any other mode ; better, even, than new.

I may here refer to what I apprehend to be a prevalent error as to the use of hard granular iron for the heads of rails. The Eba-Vale iron, which produced such satisfactory results, was not of that character ; it was a well-worked fibrous iron, and I believe all the best results have been produced from iron of that character in the heads. Some fifteen years since, an experiment was made under my observation, bearing upon this point : Rails made of fibrous and granular iron were laid alternately upon a heavy-freight-bearing road ; at the end of six months the fibrous heads showed the most marks of wear ; at the end of twelve months the granular heads began to break up, and the result was that the soft, fibrous rails wore out two of the hard granular.

In the early railroad experience a patent was taken out in England for making the heads of rails of granular iron, and at least two patents have since been taken out in this country for the same object ; but all with the same result—all have passed into oblivion, under the test of practice. There are several problems in the wear of rails which may be worthy of note. We all remember what a run the double-headed rail had in England, and how signal has been its failure ; the first head subjected to the action of the wheels became granulated and its tensile strength destroyed, so that when the rails were inverted they broke.

True to the same principle, we find that any cause which changes the position of rails in the tracks, so as to alter the bearing of the wheels upon them, causes their destruction. If they are reversed side for side to the flanges, they wear out quickly, and even if they are taken up from one point in the road and laid down in another, by which means the bearing of the wheels upon them is, of necessity, more or less changed, the granulated surface is broken up, and their durability is decreased.

INDIA-RUBBER TYRES.

From "Engineering."

Everybody has heard — through the medium principally of the non-professional press—of Mr. R. W. Thomson's road steamers with india-rubber tyres and of their wonderful performances. It has been narrated in glowing terms, "many times and oft," how they will run over soft roads and hard roads, rough roads and smooth roads, how, in fact, they appear rather to have a preference for bogs and quicksands, and places where there are usually supposed to be no roads, and how they are capable of being managed with such ease and certainty that the performance by them of Scotch reels and Highland flings are mere trifles, which they might be supposed to undertake as a relief from more arduous duties. All these things have the public been told over and over again—although not these precise words perhaps—and, as a consequence, india-rubber tyres have in unprofessional circles come to be regarded as possessed of qualities little short of miraculous, and there has arisen a demand for engines fitted with them which the original makers, Messrs. T. M. Tennant & Co., of Leith, have been unable to satisfy. Under these circumstances, we find that the manufacture of engines on Mr. Thomson's plans has been commenced by Messrs. Robey, of Lincoln, and Messrs. Ransomes, Sims, and Head, of Ipswich, while Messrs. John Fowler & Co., of Leeds, and Messrs. Aveling & Porter, of Rochester, have also become Mr. Thomson's licensees, and have become builders of engines having india-rubber tyres, but otherwise made according to their ordinary patterns. Now, we have no wish to condemn india-rubber tyres *in toto*, but we think that the time has come when an attempt should be made to set them down at their proper value, and this value we believe to be, commercially, far below that at which they are generally estimated. The chief advantages claimed for the india-rubber tyres are, that they save the engine from shocks and jars, that they give a greater adhesion than would otherwise be attainable, and that they prevent injury from being done to the roads; and that these are advantages well worth attaining we are quite willing to admit. We are also ready to acknowledge that in travelling over paved or other very hard, but uneven, roads the india-rubber tyres do good service, but the question which we consider to be open is, whether this service is commercially worth what it costs. A set of tyres for such an engine as that exhibited by Messrs. Robey, at the Smithfield show, costs about £230 for india-rubber alone, independent of the protecting chains and charges for royalty, and what has yet to be proved is whether this increase in the first cost of an engine is compensated by the subsequent reduction in wear and tear. The only way in which this can be proved is by a comparison of the cost of maintenance of an ordinary traction engine and one with india-rubber tyres doing the same work; and, at present, so far as we are aware, no such comparison is available. The next point is that of adhesion; and here we regret to say, that we must differ materially from the conclusions which have in most instances been drawn from the performances of engines with india-rubber tyres.

When Mr. Thomson first brought his engine before the public, the india-rubber tyres used by him took a direct bearing upon the ground, and there can be no doubt that under many circumstances the elasticity of the india-rubber, when thus used, enabled it to give a "grip" exceeding that obtainable with ordinary iron tyres. Experience showed, however, that the india-rubber needed protection, and this protection Mr. Thomson obtained in a very ingenious way, by surrounding his tyres with a kind of chain armor composed of thin steel plates having their ends bent down on each side of the tyre, and connected by links. In Messrs. Robey's engine at the Agricultural Hall, the plates or shoes just mentioned are 5 in. wide by $\frac{3}{4}$ in. thick, and as they are but about $1\frac{1}{2}$ in. apart it will be seen that the exposed surface of the india-rubber bears but a small proportion of the total bearing surface, and can influence the adhesion to but a proportionally small extent. It is urged, we know, that the elasticity of the india-rubber by increasing the area of the bearing surface increases also the adhesion; but although on roads of a certain class this may be true, yet we

doubt if the results are superior to those which could be obtained by the application to a traction engine of larger or broader wheels of the ordinary kind. So far, we have spoken of this part of the subject on what may be termed by some theoretical g ounds; but we have in our possession practical data which corroborate us in our opinions, and these data we shall probably shortly speak more fully. The last point is the action on the roads, and here we may again express a doubt as to whether india-rubber tyres possess any important advantage over extra large wheels of the ordinary kind. The question whether a traction engine will sink into a road, or pass over it without causing injury, is purely one of bearing surface, and regarding the matter from a utilitarian point of view we consider the thing which has to be proved by the advocates of india-rubber tyres is, not that such tyres can afford this necessary bearing surface, but that they can give it more effectively and at a less cost than it can be procured by other means.

It will be seen that throughout, our objections to india-rubber tyres are based principally upon commercial considerations, and there can, we think, be no doubt that by these considerations alone the use or disuse of such tyres will ultimately be determined. Our objections, in fact, are urged not against *elastic* tyres, but against tyres formed of such an expensive material as india-rubber now is. An ordinary eight-horse traction engine costs, say, from £360 to £380, while an engine rated at the same power, fitted with india-rubber tyres, costs £600, and the thing yet to be proved is, whether india-rubber is the best investment for this extra £220 or £240, or whether it could not be more advantageously spent in securing durability in other ways. So many traction engines with india-rubber tyres have now been built and set to work in various parts of the world, that it can scarcely be long before data are available which will enable us to estimate such tyres at their true commercial value; meanwhile we reiterate our opinion that this value will be found less than now appears to be generally supposed. That there are certain special circumstances that may warrant the employment of india-rubber tyres we admit; but that for general purposes they are worth the money they cost, we cannot at present believe.

NAVAL POWER AS AN ELEMENT OF NATIONAL STRENGTH.

From "The Iron Age."

Certain facts connected with the war now in progress in Europe, which seem to demonstrate the practical inutility of great navies for aggressive purposes in time of war, are now exciting much earnest discussion in Great Britain and other countries, whose naval power has heretofore been considered the chief element of their strength. Half a century ago, navies were the indispensable prerequisites of successful warfare on a large scale, and without them nations were almost powerless for either offensive or defensive military operations; but the fact that during the present war France has been unable to make any practical use of her vast fleet of ironclads and gunboats, forces practical men in Great Britain and elsewhere to admit that navies are fast becoming practically useless. This decrease in the effective power of navies has been brought about merely through a change in the first conditions of a successful practice of the modern art of war. France, for example, is a very strong maritime power, with the second war navy of Europe, and with wealth enough to build or charter as many transports as might be needed. Her navy is well fitted, well manned, well commanded, and to all appearance in perfect order. Even Great Britain had reason to regard the growth of the French war marine with considerable apprehension for the prestige of her own fleet of floating fortresses, and no other nation had a naval armament that could favorably compare with it in any respect. Nothing has occurred to raise any suspicion of its entire efficiency, nor are there any accidental circumstances, such as a want of coal, that have rendered it necessary for it to remain in even temporary inactivity. There is an abundance of coal at hand, or obtainable from New Castle colliers. Both the Government and the people are, and have been since the beginning of the war, very desirous of making the fleet effective, and the German States present a long

and exposed stretch of sea-coast, offering many points of attack upon which a descent could have been made without difficulty. Notwithstanding these favorable conditions, however, the utility of the French fleet in the war has been comparatively small, having in fact been limited to its power of impeding trade, of frightening the peaceful residents of one or two of the more exposed seaport towns, and of inflicting a certain humiliation on the German navy, which makes no pretensions to strength, and has prudently kept out of the way of danger.

These facts, which are too well known to every intelligent observer of the progress of military events in Europe to require extended comment, seem to indicate that, except for purposes of transportation, for which armed vessels are better adapted than transports sailing under convoy, navies have lost a great part of their former importance. The reason of this is easily explained. To make a fleet effective it must be aided by a military force capable of making a descent. Such a descent, to be dangerous, must be made by a force capable of maintaining itself upon the coast after its naval support is withdrawn; and such a force, to be safe, must comprise a total of men, horses, and field artillery which no existing navy could possibly convey at one time. No navy, except the British, could carry for any long distance more than 40,000 men. It is extremely difficult to transport a complete regiment of 1,000 men in a steamer of any available size for any voyage, however short; and when the steamers are of average tonnage and capacity, and artillery, cavalry, munitions, food, quartermasters' stores, and medical appliances have also to be conveyed, it is useless to calculate upon less than three large vessels to every 1,000 men. One hundred and twenty first-class transports make, it must be admitted, a considerable fleet, requiring a large convoy of iron-clads; yet such a fleet cannot carry in safety more than 40,000 men, and such a force cannot, without incurring risks which no prudent general would care to assume, make a landing upon the shores of an armed nation. The French might have seized Hamburg, for example, and if there were anything to be accomplished by such a demonstration they would, doubtless, have made the attempt; but they could not have held it, or, holding it, they could not have made an advance that would have materially affected the results of the war. The days are past when an army of 40,000 men constituted a formidable force. Armed nations are in the field, and no force which might be conveyed in one trip by sea could have any appreciable effect upon their colossal strength; while to make many trips is to leave the first expedition isolated, without communication, and without supplies of food or munitions in case of emergency.

Beside these difficulties in the way of utilizing naval power, however, modern science has contributed its discoveries and inventions, and, by its torpedoes and other hidden engines of destruction, made the mouths of harbors and rivers dangerous cruising ground for hostile fleets, even if composed of the strongest iron-clads. But, even without these defences, an enemy's coast cannot be made a point of attack unless something more than the destruction of life and property is to be accomplished. Modern ideas of warfare do not justify the ruthless bombardment and destruction of unprotected seaport towns, nor do they sanction the needless demolition of fortified cities upon the coast, nor the infliction of more injury upon them than is needed to overcome resistance. It will, therefore, readily be seen how much the aggressive power of modern navies has declined, and should the code of international law abolishing privateering meet with universal acceptance, and the rights of private property at sea be respected by the war vessels of all civilized nations, there will be little left for navies to do but to blockade ports, defend harbors, and serve as transports. These facts, which are forcing themselves upon the notice of intelligent men of all nations, must sooner or later meet with universal acceptance, and national policies must be shaped in accordance with them. Great navies are becoming less and less important each year as elements of national power, and the time is not far distant when a nation possessing a sufficient number of swift light-draught gunboats, adapted to its customs service in time of peace, and suitable for convoys and dispatch-boats in time of war, will consider itself as well off, in point of naval armament, as a nation that boasts a vast fleet of ponderous iron-clads.

IRON AND ITS MANUFACTURE.*

With the almost ceaseless hum of machinery in motion, which has justly been considered one of the great attractions of the Fair, now so successfully drawing to a close, still sounding in our ears, and nearly the whole of it made from iron, cast or beaten, or twisted into forms of use and beauty, it is certainly quite unnecessary to expatiate on the importance of iron, or its constantly recurring and ever-increasing necessity in our daily life. The greater or less use of iron has well been pronounced a fair measure of the degree of the real civilization, and extent and variety of useful industry, which prevail in modern countries, and is perhaps the surest single means of readily judging of any people's position in the family of nations. The manufacture of iron was one of the earliest industries requiring joint or associated action, or the labor of several individuals to produce one specific end, the reduction of iron ores having begun very early, and being too difficult for one man to accomplish, to any extent, unaided; and its production quickly necessitates a more or less crude commerce, for nowhere does a family or tribe make its own iron without also producing a certain surplus to be bartered off to the less fortunate or less skilful; and this manufacture and barter, begun almost as soon as men ceased to live entirely by the chase, has continued constantly supporting or stimulating manufactures and commerce, until they have attained the stupendous development of our own day, when every sea is blackened by the smoke of engines of iron steamers, and the wild beast is startled on every prairie and in every jungle by the shriek of the iron horse running on the iron rail.

For what uses iron has already become a universal convenience or necessity we all know, and the catalogue is too long to be even run through in a single afternoon; but after the wonderful strides of the past half century in the manufacture and consumption of this the really precious metal, what man so bold as to attempt a successful prophecy of its future utility; while it is almost as difficult to trace its early real history, stretching back into the dim twilight of man's existence, when shadows and realities are inextricably mingled. That Tubal Cain was one of the earliest workers in iron, is of course a familiar fact to every one who has read an article or heard a lecture upon iron, and its tolerably frequent use seems to have been familiar to many of the Bible writers. Og, King of Bashan, had an iron bedstead; chariots of iron, harrows, and other tools of iron, are spoken of, and a pen of iron conveyed a sufficiently familiar idea to make it a convenient figure for the prophet Jeremiah; while the Israelites were early promised, as specially desirable, a land whose stones are iron. In Homer, both iron and steel are mentioned, and, in the 23d book of the Iliad, a mass of iron, only so large as a strong man might throw to some distance, is offered as a valuable prize at the funeral games of Patroclus. In the words of Bryant's spirited translation,

> "Again Pelides placed before the host
> A mass of iron, shapeless from the forge,
> Which once the strong Eetion used to hurl,
> But swift Achilles, when he took his life,
> Brought it, with other booty, in his ships
> To Troas. Rising, he addressed the Greeks:
> 'Stand forth, whoever will contend for this,
> And if broad fields, and rich, be his, this mass
> Will last him many years. The man who tends
> His flocks, or guides his plow, need not be sent
> To town for iron, he will have it here.'"

At Babylon the huge stones of the bridges were held together by bands of iron, fixed in place by molten lead. Later, Thucydides tells us that the walls of Pireus were fastened in the same way. The Ninevites made tools of iron; and small objects of art made of iron, or iron and bronze, were found by Layard in tombs of early date. And through all the nations of high antiquity, iron is mentioned almost always in a way that shows it to have been a partially common, but always highly esteemed metal. Indeed, from the difficulty of working it with the primitive means at the command of men just emerged from barbarism, it was constantly held at a high price. Iron was exchanged for brass, weight for weight, and, whatever the age of the world, we find substantially the same fact at the same stage of a nation's develop-

* An address by A. W. Humphreys, Esq., Treasurer of the Sterling Iron and Railway Company, before the American Institute, New York, November 1, 1870.

ment; only 150 years ago, Botachoff, in Russia, having bartered iron for an equal weight of copper coin. So, also, in the older ages, as now, those best skilled in the production and manipulations of iron held a certain pre-eminence, and, in some instances, almost the only claim some of the smaller peoples have to a mention in the page of the historian, or which prolongs to our day that slight recollection, or indirect mention, which is their share of fame, has no title but their ability to wrest this metal from the tenacious grasp of combined impurities, and thus make it useful to themselves, and to their neighbors a coveted implement or dreadful weapon.

Thus the Chalybes, a once powerful Arminian race, famous formerly for the quality of their iron, continue to celebrate their superior production and perpetuate their own memory by furnishing us the root of the word chalybeate. They, as other early iron-workers, left slight record of their processes or operations; Aristotle, indeed, mentions that their arenaceous ores were washed, and he also partially describes the operation of making wootz in India; and Diodorus Siculus says that in the Island of Ethalia the ores were roasted, broken fine, perhaps partially reduced to blooms, and sold for iron-making; but these and other scanty particulars contain but little of instruction or warning for us. So of the slight knowledge we possess of the manufacture and treatment of iron in Ancient India, China, and Egypt, where there is plenty of evidence of its early use and importance, but only meagre information as to the methods of obtaining it from the ores, and only deserve notice as showing how soon this metal began its influence and proved its importance. We are only sure that it was *wrought* iron that was produced and employed, and not *cast* iron, which is a comparatively recent production, and it is probable it was all obtained by a primitive direct process, from rich and easily reducible ores.

Down to the time of the Romans iron was too scarce and high to be of general use, but they employed it with comparative freedom; and perhaps, in the absence of files of any scientific press, which now quickly promulgates any new discovery, and the progress made in the adoption of new materials, or fresh applications of old ones, nothing shows more succinctly the change which had taken place in the increased use of iron under that powerful race, than the fact that Homer speaks of death as a sleep of brass, while Virgil, with the same idea in his mind, conveys it familiarly to his public by calling it a sleep of iron. The Romans introduced the manufacture of iron to the Iberian Peninsula, and Spain for a long time furnished not only metal to her neighbors, but also skilled workmen to those who wished to enter upon its manufacture for themselves; and probably France is indebted to Spain for what early knowledge of iron working she possessed, while through France the practice passed on to Germany, and settling among the Hartz Mountains, its numerous forge-fires helped furnish that extraordinary stock of goblin stories and fairy tales which were the delight and terror of our childhood. Further East and North, in Russia and Sweden, a knowledge of iron metallurgy probably came to them through the Scythians in a rude way from still farther East, where the hordes of Indiamen had long made the celebrated wootz, a steel of high quality, though made in the most primitive way, or perhaps from China, where iron and its magnetic properties have been known for ages. But at a later date all knowledge of the art of this manufactnre as now practised, came mainly from England, and therefore it is to her progress that we turn for the proper history of iron and its improved manufacture, as we know it. In Britain, it is extremely probable, but not certain, that the use of iron was known long before the invasion of Cæsar, though we are entirely ignorant of what may have been the method of its manufacture. With the occupation of the southern end of the island by the Romans came quite extensive workings of the rich ores near the sea, and subsequently the Danes carried on the reduction of the same deposits of ores so largely, that at a still later date the piles of cinders left by them supplied many blast furnaces for a long time, with material for the production of pig iron, the more perfect operation of the blast furnace extracting iron from what was worthless slag to the crude operations of Romans and Danes.

The method employed by all the early workers of iron of whose operations we

know anything, was similar to that still in use in India, in Borneo, in Madagascar, and in Africa, and consisted in heating as hot as a natural draft of air, or that artificially supplied by the crudest of bellows, would permit, rich ores of iron in contact with incandescent charcoal, and hammering the viscid mass until the earthy impurities were expelled and an irregular shaped lump of nearly pure iron remained—the "mass of iron, shapeless from the forge," of Homer, and which—still produced, by slight modifications of the same process, in numerous localities throughout the known world—we call a bloom of iron, from the old Saxon word *Bloma*, the *Bloma Ferri* of the Doomsday Book—and which is hammered into bars or tools as wanted. This early manner of producing iron continued, with slight change, the universal method until the discovery of cast iron, and, together with its various modifications and offshoots, patented and unpatented, are all different branches of what is known as the direct process of making iron, being a production of malleable iron directly from the ore, at one process, in distinction to the now more common manner, called the indirect method, which first smelts the iron ore by means of the blast-furnace, and then eliminates from the resultant pig iron its carbon and other impurities, by puddling or other means, until malleable or wrought iron is obtained. That this indirect and roundabout way should be now generally adopted, seems almost paradoxical, and an inventor of one of the improved direct processes, for such inventors are numerous, being led by an *Ignis Fatuus* to attempt the short cut across, instead of making the best of the road around, asks, very pertinently, why convert iron already malleable (in the ore) into cast iron, to be reconverted, at much labor and cost, into malleable iron again? The question is an obvious one, and the only answer is, that thus far the indirect process has proved the most useful for the reduction of the majority of workable ores, in large quantity, all direct processes hitherto employed being applicable only to rich, selected, and easily reducible ores, wasteful of fuel, prodigal of labor, or irregular in their result. It is undoubtedly the dream of every iron-smelter who thinks much, or dreams at all, to find some method of obviating the use of the blast-furnace, but no commercially successful way has yet been found of realizing this dream on a large scale—that is still one of the not improbable achievements of the future.

The terms *wrought iron* and *cast iron* may occasionally lead to confusion and misunderstanding, and it should be constantly borne in mind that iron is iron, however and from whatever ores obtained. Wrought or malleable is nearly pure iron, and is malleable and ductile, while cast iron, as well as pig iron, which is only a form of cast iron, is a compound of iron and carbon, with some other impurities usually existing previously in the ore in too large or too intimately combined quantity to have been entirely removed by the action of the blast furnace, and is neither malleable nor ductile. Malleable castings, of which keys, the iron-work about a horse's harness, and many small articles are made, is cast iron in which carbon was originally almost the only impurity, and which, by a process of cementation, has been so nearly removed as to make the castings slightly malleable, though destitute of fibre, which is developed in wrought iron, but not at all ductile.

To properly trace the history of the present iron manufacture we have only to go back about 500 years, to the development of the process of making pig iron, by the blast furnace, at a date which cannot be fixed with precision, but about the beginning of the 15th century. It is probable that the gradually increased height of the little furnaces or forges, formerly in use, with the greater intensity of blast, also gradually increased, finally led to the complete melting of the ore, and so, by the final addition of some earthy flux, cast iron was obtained; but where and by whom the change was turned to any practical account is unknown, though the first furnaces erected to make only pig iron seem to have been in France, or what is again, unfortunately, the debatable land between France and Germany; and one of the earliest English makers of pig iron imported a workman from France to teach him the art. But if France can claim the origin of the manufacture, England soon took and has since maintained the front rank in the quantity made, though to Sweden we still look for a superior quality of many descriptions of

iron. The quantity of iron made in England was for a time seriously checked by want of fuel. Down to the beginning of the 18th century, charcoal had been the only fuel employed to any extent in the manufacture of iron, and the immense forests of Russia gave her, for a time after the manufacture was established there, a certain advantage, and she sent large quanties of iron to England, where the drain of timber for iron making had been so great, that in 1851 stringent laws were passed to prevent the consumption of timber in any new iron works within 22 miles of London, or 14 miles of the Thames, such legislation being necessary to prevent a famine of fuel, the whole kingdom being then dependent on wood; this and some additional legislation having failed of its object, it was finally forbiden to use any timber for charcoal for making iron.

Some fuel was necessary, and the Dudleys spent much time and money in their experiments in the use of pit coal, finally succeeding in making iron by its use, but, through various obstacles, many of them thrown in the way by jealous charcoal iron-makers, not being able to establish it as a regularly accepted article.

For nearly 80 years after the final abandonment by Dudley of his persevering trials and partial successes, nothing was accomplished toward the practical solution of the problem, until, finally, in 1735, Abraham Darby, of Colebrookdale, succeeded where so many others had failed, and the manufacture began a fresh period of prosperity, though still only partial, for the introduction of mineral coal necessitated further improvements which the state of the mechanical arts made still impracticable, and England continued partially dependent on Sweden and Russia. In 1760, Smeaton erected, at the Carron Works, the first large blowing cylinders, and these, furnishing the larger quantity of air necessary with pit coal, or rather the coke from pit coal—raw coal being yet unused—showed iron-masters in what direction lay the chief difficulty hitherto preventing the complete success which had been expected to follow Darby's discovery, while, at about the same time that Smeaton was constructing his large cylinders, Watt was improving the steam engine, and he had so far perfected it, with the aid of Boulton, that in 1788 iron-masters were beginning generally to employ his double engine, which supplied the power necessary to work the large blowing cylinders, thus completing what Darby had begun; but it extended no further than the blast furnace and the manufacture of pig metal. Another step had been needed for the speedy and economical conversion of pigs into bars; this was supplied theoretically by a patent issued to Peter Onions, in 1783, in which the *rationale* of the puddling process was described, and the principles involved fully covered. The next year Henry Cort, of Gosport, took out a patent covering the practical use of the puddling process, and the use of grooved rolls, and to Cort is generally ascribed the merit of both inventions; and he has been styled the Father of the Iron Trade; although, as a matter of fact, the mode of puddling described by neither Onions nor Cort is precisely followed at the present time. Cort spent a large sum in perfecting and introducing his inventions, and had what seemed the shrewdness to get a Government official interested in his patent, and to furnish a part of the capital necessary, and Onions sank out of sight. Cort's Government friend was caught, however, in a defalcation or "irregularity," having, in fact, stolen the money he advanced to Cort. The Government seized the patent; it was locked up in court, and Cort finally died a poor man, ruined by what has proved to be the means of wealth in England.

These improvements laid the foundation of England's supremacy as an iron producer; they speedily came into general use, and the production of iron, aided by the fostering care of the Government and the unusually high price of foreign iron, rapidly increased. As the completion of these improvements, about 1790, was the commencement of the present era of iron making in England, it may be worth while to consider, for a moment, her previous and subsequent position in this industry, from a commercial point of view. The quantity of iron made in the Kingdom nearly sufficed for the consumption of Great Britain, until the passage of the stringent Fuel laws above spoken of, and there were neither imports nor exports of any great quantity, until the seventeenth century. Statistics of the whole product of the British Islands previous to 1715 are not to be had; in that year there were

estimated to be about 300 furnaces in operation, and the price of pig iron was about £6 per ton; from the dearness of fuel and the operation of the laws against the employment of charcoal at iron works, the production gradually fell off, until in 1740 there were only 59 furnaces in operation, producing 17,350 tons per annum of pig iron, while the net imports of iron of all descriptions, mainly from Russia, Sweden, and the American colonies, were about 20,000 tons. Then came Darby's success with pit coal, and the make immediatly began to increase, and continued to do so moderately, until, in 1788, the total production of Great Britain was 68,300 tons, and her net imports only about 15,000 tons. Then came Smeaton, and Watt, and Cort; the duty on bars was put at 56s. per ton, the value of bar iron being about £18 per ton, and the manufacture fairly began the prosperity it has ever since retained, with occasionally a dull period of short duration. In 1796, an additional duty of £1 per ton was laid upon bars, a rise of about 30 per cent. took place in Russia, and, to quote Tooke, "the produce of iron proceeded so rapidly, that, with the aid of further duties, amounting almost to a prohibition of importation, it not only kept pace with the increasing demand, but actually nearly superseded the use of foreign iron in this country, and furnished a surplus for exportation." In 1797 the production was 125,000 tons. So strong had been the stimulus that, in 1801, there were building, or in blast, 47 new furnaces, 125 being then the total number of the old ones. Let it be borne in mind that no new process had been discovered since 1790, nor had any special improvements been made, meantime, in furnace machinery; the increase was due entirely to the increased demand, to a rise in foreign iron caused mainly by this increased demand, and by the action of the Government in so arranging the duties that Great Britain might herself reap the full benefit of the changed circumstances, carefully sustaining the feeble steps of this branch of industry while thus in its infancy. In 1806, the total number of furnaces in Great Britain was 173, making 258,000 tons per annum, an average of less than 1,500 tons to each furnace. In 1825 there were 364 furnaces, of which 261 were in blast, making 581,000 tons per annum. The duty at this time on bar iron was £6 10s. per ton, having been gradually raised to this figure since 1796, and Great Britain, from being an importer, had so changed her relative position in the iron world, that her net exports were 90,000 tons.

There was still no further change in modes of manufacture, but in 1828, Mr. J. B. Neilson, of Glasgow, took out his patent for the use of heated air, instead of the cold blast, which had alone, until then, been used to support internal combustion in the blast furnace. Whatever merit we may gladly concede to the predecessors of Mr. Neilson for their improvements, it is certain that no single invention in the manufacture of pig-iron has been followed by so great benefits or occasioned so marked advance as the use of the hot blast; although it deserves to be called a discovery rather than an invention, for, in the words of Dr. Percy, "there is no reason to believe that the patentee had, at first, any adequate conception of the value of his invention, and the great influence it was destined to exert upon the smelting of iron." But the iron-masters were not slow to perceive the great advantages it offered, and promptly availed themselves of them, so that by 1835 it is said that the heated blast was in use at every furnace in the kingdom, with a single exception, and the quantity of coal necessary to smelt a ton of iron was reduced, in 3 years, from 1-20 tons, coked, to 2¼ tons, used raw, actually consumed in the furnace, and 8 cwt. required to heat the blast, or a total of 2 tons 13 cwt. of raw coal, the Calder Works having demonstrated, in 1831, the needleseness of coking when hot blast was employed, while later the expense of any extra fuel for heating the blast was dispensed with, the waste gases from the top of the furnace being used for that purpose. This latter improvement originated in France, where, in 1811, M. Aubutot took out a patent for their employment and utilization, reserving to himself, however, only their use as far as connected with his own business, the cementation of steel—giving to iron-masters, with singular generosity, not only all the benefits they could derive in other ways from his patent, but carefully instructing such as chose to apply to him in the best way he knew of collecting the gas, although

he foresaw at least a part of the enormous advantages which would finally result from his idea. But little was actually done with the waste gases, however, to assist in smelting, until, in 1854, Mr. Budd took ont a patent in England for the utilization of the gases for heating the blast, and soon applied his principle, not only to the stoves, but to the generation of steam in the boilers, at his furnaces, and since that time it is almost the universal practice to use only the heat from the combustion of these gases for those purposes, and at some furnaces their employment is carried still further, and ore is calcined by them in kilns especially adapted for that purpose ; though whether there is as yet any real economy in this, at large furnaces, remains, to a certain extent, an open question. The people of the United States have especial reason to hold Mr. Neilson in grateful remembrance, for, without hot blast it would be almost absolutely impossible to smelt iron with anthracite coal, the experiment of doing so with cold blast having been thoroughly and carefully but unsuccessfully tried in the United States, in France, and in Great Britain, the earliest recorded trials having been made as early as 1820, near Mauch Chunk, Pa., and next in France in 1827 ; but it was only when aided by hot blast, that Mr. Crane, in Wales, with ovens built by Mr. Neilson himself, finally achieved success with this king of fuels, in 1837, though Geissenheimer had in 1833 taken out a patent in the United States for the use of anthracite, but with no practical results. Again, at Mauch Chunk, in August, 1838, this time with hot blast, and, it is asserted, without a knowledge of Mr. Crane's success, an attempt was made to employ the Pennsylvania anthracites, and a blast of five weeks is claimed to have been perfectly successful, the furnace being owned by Bauman, Guiteau & High. They stopped, from want of ore, in January, 1839, and after somewhat enlarging the furnace, again blew in at the end of the following July, and continued in blast till November of the same year, having produced about 2 tons of iron per day, when working best, with a blast heated to about 400 deg. The size of the furnace was 5½ ft. bosh by 21½ ft. high. The quantity of coal consumed per ton of iron made, I am unable to state.

The Pioneer furnace, at Pottsville, was the next furnace successfully employing anthracite coal, and the same site is still occupied by an anthracite furnace owned by Messrs. Atkins Bros., though the old stack was torn down in 1853, and a larger furnace built on the same foundations. It was blown in by Benjamin Perry, with some general assistance from David Thomas, in July, 1839, and completed its first blast in January, 1840.

The above statements regarding the first use of anthracite seem to me well authenticated by documents written by the parties interested, at, and immediately after, the dates mentioned above, and I believe may be relied on, though there has been some controversy upon whose brow should rest the *corona muralis* of success in this peaceful struggle, and I have taken corresponding pains to determine the conflicting claims.

In a general way, it is sufficient to say that from 1839 dates the employment of anthracite coal for smelting iron in the United States, and the production of this description of iron has, with various ebb and flow, finally reached the handsome quantity of 971,000 tons made in 1869. The primal development of the use of anthracite we must concede to Mr. Crane, in Wales, but the American iron-masters long ago left their Welsh competitors far behind in the production of this particular description of pig-iron, whether there be considered the quantity made, the size and general completeness of the furnaces, or the quality of metal produced, the generally poor character of the Welsh coal, and its excessive decrepitation upon the application of heat, having been powerful hindrances to the growth, at the place of its birth, of this particular branch of iron industry, Wales having made, in 1869, but 28,000 tons of anthracite pig iron. With hot blast and the use of anthracite begins the real history of the extensive manufacture of iron in America. But this sketch would be quite incomplete and unsatisfactory without an attempt to follow, as accurately as possible, the progress of the early iron-workers on this continent, though the record is very imperfect, our forefathers having had quite enough to do to maintain their individual footing without giving themselves much anxiety about general statistics ; and whoever traces carefully the fluctuating fortunes of the

predecessors of the present iron-masters of this country will find that the soldier patriots of Valley Forge were not the only men whose faithful picket-duty in the cause of American independence was attended with immense personal sacrifice and heroic self-denial.

The Red Indian knew nothing of iron extracted from the ore, but sometimes fashioned weapons out of ore as from any tough rock. The first known iron works in America were erected near Jamestown in Virginia, in 1615 or 1619, but after an unprofitable existence of only 3 years, the furnace was demolished by the Indians, and all the inhabitants of the surrounding village murdered, thus ending that initiatory enterprise. We hear no more of any very strong efforts toward the production of iron until, in 1644, forges were established at Lynn and Braintree in Massachuseets, and though only moderately successful, maintained their footing, and iron and its manufactures have never since ceased to form an important proportion of New England industry, nor to foster inventive skill, Joseph Jenks having, as early as 1655, by changing the shape of the common scythe from the old English form, short, clumsy, and ineffective, into the tool we are familiar with, commenced the development of that wonderful aptitude for improving the common utensils of life which we call Yankee genius, and of which the results are now found wherever the steel-trap has replaced the pitfall, the bow and arrow retired before the rifle, or the compact and economical cast iron stove driven out the cold porcelain stove of the Germans, or the warm, but wasteful open fire of the English.

The small ponds in Eastern Massachusetts and of Rhode Island for more than a century supplied an unknown number of furnaces and forges with bog ore, which, by the aid of charcoal from the then dense forests, was smelted into pigs or forged into blooms, and, during this century, the manufacture of iron had been successfully established in most of the Colonies, from Massachusetts to Carolina, but no records worthy of credit now exist to state the definite extent of the total product. The exports of iron, beginning in 1717 with 3 tons, gradually increased until 1750, when 2,930 tons were exported. In that year the British Parliament removed the import duty on pig iron made in the Colonies, and on bar iron if brought to London, but forbade the erection or maintenance of any mill for rolling or slitting iron, or any plating forge, the object being to get a new source of supply for raw irons at a time when the home-make had become insufficient to supply the demand, and at the same time prevent the Colonies from producing iron further advanced than the pig, lest England should lose anything of her own importance as a manufacturing centre. In 1756, a new law opened the other ports of Great Britain to Colonial bar iron, and American exportation rapidly increased, though in a small way, the total in 1760 being 2,700 tons; in 1755, 4,342 tons, and in 1771, when it reached its maximum, 7,525 tons. The importations, meantime, had been small quantities of Russian and Swedish iron, say from 100 to 500 tons per year. Further than these scanty records of exports and imports, there exists no authentic information of the condition of the Colonies, as a whole, prior to the Revolution. With the outbreak of the war, exports naturally ceased, and the demand for war material not only taxed existing mills to the utmost, but caused a rapid extension of the industry, which was suddenly checked, and many individuals ruined, by the large quantities of foreign iron brought in as soon as the close of the war again opened our ports, England having in the mean time largely increased her manufacturing facilities.

The industry remained extremely depressed until the passage of the first Tariff bill in 1789, the rates in which were raised in 1792, again in 1794, and the quantity of iron made steadily increased. In 1810 the United States contained 153 furnaces, making 53,908 tons of iron. From the lack of any compulsory returns of manufacture to the Government, year by year, and the want, only recently supplied, of any association among iron-masters, through which, for mutual advantage, such information could be obtained, there are but imperfect records of the quantities of pig iron made in the United States. I will give all the figures for which any degree of correctness can be claimed down to 1850.

In 1810 we made	54,000 tons.
In 1828 we made	130,000 tons.
In 1829 we made	142,000 tons.
In 1830 we made	165,000 tons.
In 1831 we made	191,000 tons.
In 1832 we made	200,000 tons.
In 1840 we made	347,000 tons.
In 1842 we made	215,000 tons.
In 1845 we made	488,000 tons.
In 1846 we made	765,000 tons.
In 1847 we made	800,000 tons.
In 1850 we made	564,000 tons.

In 1854 there were made 716,000 tons, and from then until the breaking out of the Rebellion the yearly make was from 700,000 to 900,000 tons, varying slightly, increasing and decreasing year by year.

In 1863 the make was	947,000 tons.
In 1864 the make was	1,135,000 tons.
In 1865 the make was	931,582 tons.
In 1866 the make was	1,350,000 tons.
In 1867 the make was	1,461,000 tons.
In 1868 the make was	1,603,000 tons.
In 1869 the make was	1,916,000 tons.

England, during these years, had of course largely increased her production. In 1818 she made 300,000 tons, and gradually augmented this quantity, until in 1835 it first reached 1,000,000 tons.

In 1840	1,500,000 tons.
In 1847	2,000,000 tons.
In 1850	2,500,000 tons.
In 1854	3,000,000 tons.
In 1856	3,500,000 tons.
In 1862	4,000,000 tons.
In 1863	4,500,000 tons.

And since then it has fluctuatingly increased to 4,900,000 tons in 1868, and about 5,400,000 tons in 1869.

For the sake of following the history of the commercial progress of our own manufacture of iron, I left the consideration of gradually evolved metallurgical improvements at the introduction of the hot blast and anthracite, from 1830 to 1840. We have seen that a century was occupied in making the five great steps which brought the metallurgy of iron from the comparatively primitive state in which Darby found it, to the threshold of its development in America—namely, the use of mineral coal, of the steam engine, puddling and rolling, hot blast, and the use of anthracite.

The improvements since have been marked in their results, but there has been no one, in the manufacture of pig metal, which has given the trade any single great impetus, and of the several, more or less famous, which have facilitated the making of wrought iron, of steel, of semi-steel, of homogeneous iron, and their various compounds and shades of difference, I have not time to speak—nothing less than a full afternoon could do them a moiety of justice.

In order to appreciate what has been done since 1840, let us glance at the then condition of the iron-making process: The ore was charged, with its accompanying fuel, into the open tunnel-head of furnaces of about 12 ft. bosh and about 45 ft. high; combustion of the fuel and reduction of the ore was effected by means of a blast of say 500 deg., at a pressure of about 3 lbs.; a part only of the waste gases were at all utilized by being taken from some distance below the top of the stack, before they had become really "waste," frequently deranging the proper working of the furnace, while the portion thus taken was of but very little use, by reason of its insufficient mixture with atmospheric air and subsequent only partial combustion; the result was a consumption of 1½ to 2½ tons of fuel per ton of iron produced, the quality of the metal made was decidedly variable, and the production per week about 70 tons. The pig iron was then puddled entirely by hand to make wrought iron, and the purified product rolled into merchant bars, not a rail having then been rolled in the United States. Steel was only made by the old-fashioned processes, either slowly and at great cost, or, if more quickly, of variable and inferior quality. The lines of demarcation between the only three forms of iron then recognized, cast iron, wrought iron, and steel, were strongly pronounced and definite.

It would be unfair not to mention the first use of the raw bituminous coal west of the Alleghanies, as the production of iron with this fuel will ultimately quite surpass in quantity that made with anthracite. David Himrod is said to have been the first to employ it, uncoked, in 1845, being driven by a strike of his workmen to either attempt this or blow out his furnace. He tried the raw coal, and with complete success, thereby opening the door to the manufacture, in 1869, of 550,000 tons of iron made with bituminous coal.

Since 1840, the blast has been gradually made hotter and hotter, and the means of economically and regularly giving the air a temperature of 1,000 or more degrees, have naturally attracted much attention, resulting in the patenting

of various stoves, of which Player's and Cowper's plans may be considered leading methods of accomplishing this end—Player's operating by burning the gas from the furnace in a separate combustion chamber below the pipes through which the cold air passes to be heated, and allowing only the heat to come in contact with these pipes, instead of permitting combustion to take place in the oven inclosing the pipes, as was the old plan, and the results have been very favorable, though it is fair to state that part of the gain from the use of Player's oven arises from the increased number and somewhat changed shape of the pipes themselves.

Cowper's patent, said to be a revival of an old Scotch idea, is but little known, practically, in this country, though favorably used in England, and is founded on the Siemens' regenerative principle, a cellular mass of brick-work being first raised to a high heat, and this heat then imparted to the blast which is made to pass through it, while a similar mass of brick-work is being heated, ready for use as soon as the first shall have become partially cooled. Whitwell's ovens, acting on the same principle, avoid some of the objections raised against Cowper's stove, the principal one being that it clogs readily with dust and is expensive to clean. This Whitwell obviates by making his brick-work into largish compartments instead of cellular. It is claimed that the blast can be heated to 1800 deg. by this stove, and a regular working heat of 1,400 deg. be steadily maintained. To estimate properly the great importance of improved devices for heating the blast, it should be constantly remembered that for every ton of material charged in at the tunnel-head, at least three tons weight of air is blown in at the bottom through the tuyeres; and it requires but little further consideration to impress on any one the great difference that must be exerted on the work of the furnace if this air is put into the furnace already heated, or is introduced cold, and the work of heating, it thrown upon the fuel in the furnaces which should find abundant employment in smelting the ore only. There is also an unexplained advantage in the use of heated blast, it being a fact that, if the air supplied to a common laboratory blow-pipe be heated to say 500 deg., many substances previously infusible by the common blow-pipe frame are readily melted. Why, is yet unknown.

The complete closing of the tops of furnaces is another great improvement with most ores; and, as a rule, whenever a flame is visible at the tunnel-head, we may be sure that a large waste is taking place. The best device yet arranged is what is known as the bell and hopper, or cup and cone, which consists of an inverted truncated hollow cone of cast iron, the cup or hopper filling the throat closely at the top, but considerably smaller at the lower end than at the throat. In this is suspended a cast iron cone by a chain attached to its apex, and so arranged as to be raised or lowered at pleasure; its largest circumference being larger than the downward end of the cup, closes the top of the furnace completely when raised against the cup, and, when lowered, leaves an opening of several inches all around it. Through this the furnace is charged, and as each charge passes through it is immediately closed by raising the cone, and kept shut until time to admit another charge. The furnace gases, prevented by the tightly-closed cup from passing out of the furnace top, and collected in the open space around its lower end, pass out to the hot-blast ovens, boilers, and roasting-kilns, through proper flues. The principal object of the closed top is that all the gases may be secured for use; but it has other incidental advantages, the cone distributing the raw materials much more evenly than practicable with simply a large hole in which to dump them, while the ability to close or open the throat assists in the general control of furnace action. An excellent English authority says that 600,000 tons of coal are saved in their Cleveland district alone, per annum, by the use of closed tops.

Passing at once from the top to the bottom of the furnace, we find an attempted improvement, not yet generally introduced, in Lurman's closed hearth. This plan builds up the hearth in a complete circle, leaving only a small hole at the bottom for the iron to run out, and, where the cinder notch usually is, a tuyere one and one-half inches in diameter, is inserted, through which the slag runs off as fast as formed. The advantages claimed, and, in some places where this

hearth is introduced, fully realized, are a hotter hearth, there being no heat wasted to keep up the temperature in the useless channel between the hearth and the dam; while the tuyeres, instead of blowing into the cinder, as is frequently the case, are inserted at a level of about nine inches about the slag outlet, so that the materials to be smelted have the full and uninterrupted effect of the blast; less time is required for casting, while the hearth is kept so hot as to have no tendency to "grow up," and, there being no fore hearth, there is no crust to break up, thus saving much time; and, as the hearth has no opening through which the materials can blow out, a much higher pressure of blast may be maintained.

Quite in the region of theory, as yet, is the plan of Herr Schintz, of Strasbourg, a metallurgist who has made the action of blast furnaces a special study, and who has suggested innovations which have a plausible appearance of success. It is of course known that of all the atmospheric air blown into the furnace, whether hot or cold, a large proportion consists of nitrogen, which assists not at all in the combustion of fuel, and is of very doubtful utility in any way in the furnace, while it is certainly harmful in diluting the useful gases, and occupies a deal of space that could be much better employed, to say nothing of the fuel necessary for heating the nitrogen along with the oxygen in common air. Herr Schintz's theory has for its object the elimination of part of the great surplus of nitrogen, by working the furnace partially with solid fuel, in the ordinary way, and partly with carbonic oxide, manufactured in separate generators, and forced into the furnace through separate tuyeres, with the ordinary blast. It is applicable, as far as developed, only to hot blast furnaces, and the details are too long to find a place in this paper, but the plan is worthy the intelligent consideration of iron-masters, being theoretically correctly founded.

The size and shape of the furnace have gradually undergone great changes, the whole interior being originally square in horizontal section, and the hearth was made square, or a parallelogram, long after the upper portion of the furnace became circular. When the interior was square, the exterior was naturally so, and was generally formed of stone masonry heavy and massive, but the heavy masonry seems to have no special advantages beyond making a picturesque ruin when abandoned, and the later furnaces, in England and our own Western States, are of what is called the cupola style, the heavy masses of stone at the corners having given place to simple iron columns, supporting a large iron ring, on which is built the stack, the exterior of the fire-brick which forms the hearth being open all around, and the stack itself consisting of the fire-brick lining, with a course or two of red brick external to it, and surrounded by boiler plate securely riveted together, the whole looking not unlike a brewer's huge vat, standing on four legs. The vertical section of the interior varies with the fuel and ores to be employed, and somewhat also according to local fashion; the precise shape, in any locality, is best attained by careful observation of the furnace when blown out. The constant tendency of the best English practice has been to enlarge the hearth, and with beneficial results, though on the continent of Europe, generally, the small hearths are still adhered to. The throat has also been much enlarged from the size common thirty years ago, and the proportionate height of the furnace also increased, where the fuel is strong enough to bear it without danger of being crushed by the increased weight of the larger mass of ore, or the pieces of the crude materials so fine as to obstruct the blast, both which changes have unquestionably increased the economy of fuel.

Now, then, after a lapse of thirty years—since 1840—a combination of the various changes and improvements gives furnaces of 27 feet bosh and 105 feet high; a blast heated at will to 1,400 deg., blown with a pressure of from 5 to 7 pounds per square inch, into the upper portion of a roomy, circular hearth, tightly closed, except the absolutely necessary apertures to permit the egress of scoriæ and metal, and after supporting combustion, which must produce a heat of at least 3,000 deg., and mingling with and partially forming the gases evolved, reaches the tunnel-head at a temperature of about 500 deg., and there, finding the throat entirely closed, is compelled to seek its exit through side flues, and do still further service—after being mixed with atmospheric air—in heating a fresh supply of

air, or generating steam to force it, in its turn, through the same route; the result being the production at a single furnace, of 700 tons per week, or from one stack, in 1870, more than double the quantity all Great Britain made in 1740, and made by the use of less than a ton of fuel per ton of iron.

The total quantity of pig iron made in the United States in 1869 had a greater value, in this crude state, at average prices, than all the gold and silver produced in our country, by some $5,000,000. Throughout Europe, the advance in iron metallurgy has been scarcely less marked than here and in England.

	Tons.
In 1845, France produced	440,000
In 1869, France produced	1,380,000
In 1845, Germany produced	180,000
In 1869, Germany produced	1,220,000
In 1845, Belgium produced	150,000
In 1869, Belgium produced	863,000
In 1845, Austria produced	175,000
In 1869, Austria produced	395,000

The total quantity of iron made in the world in 1869, varied but little from 11,700,000 tons.

The changes in the various modes of manipulating pig iron and advancing it to a finished article have been extraordinary and unexpected, and are still being made or attempted with a rapidity which it is difficult to keep pace with, and to which I have not the time to refer, even by name, but must omit mentioning, as I have done many of the slight changes in blast furnace operations.

For still greater improvements in making pig iron, aside from great discoveries of new principles, especially in this country, where, I am sorry to say, even the advantages already gained are not as fully seized upon as might have been expected, we must look to a more general and thorough knowledge of the principles which govern furnace working, a more intelligent combination of various ores, so to use as little flux as possible simply as flux, making different ores perform that function for each other, or using a proper flux where a separate material is really necessary; to the use of fire-bricks made from materials best adapted to resist the corroding influences of the ores to be worked, and to a general practical recognition of the fact that the production of pig iron is essentially a chemical operation on a huge scale, where even slight variations from the really best way are productive of enormous waste. The above objects can only be attained by frequent careful analyses of all the materials employed, and then by carefully modifying their proportions in a scientific manner.

In the mechanical portion of the labor of smelting there needs also the most thorough economy, not, however, always considering that an economy which is simply a neglect to do, in the preparation of the burden, from fear of the first cost, that which it really costs more to compel the furnace to do after the materials are charged in—such as roasting hard ores, thoroughly mixing ores, coal and flux, and reducing the pieces of each to the sizes proper for speedy action upon each other in the reduction zone of the furnace; also avoiding, as especially false economy, the hap-hazard way of charging, which is so frequent, for uniformity of action can only be secured by uniformity of means. I may perhaps be allowed to mention, as one excellent check upon this, the stock-house scales of Riehle Bros., which are on exhibition here, and which I know, from some years' use, to be extremely well adapted to that end. In our changeable climate, it may well be considered whether it is not also the best economy to protect, by non-conducting coverings, all pipes conveying steam or heated air, the loss by radiation being simply enormous, at many furnaces. Stock-heaps should be so arranged that the materials may be received and placed at the tunnel-head with as little handling as possible, bearing in mind constantly that pig iron is nearly all labor, and that it should be reduced as much as possible, not necessarily by a decrease of the rewards of labor, so that our men may be compelled to live in squalid hovels, with scarcely the necessaries of life, and none of its comforts, or, as Mr. Wells has shown the Belgian workmen, with meat, cheese, tea, eggs, fruit, and artificial light of any kind so seldom employed as not, all together, to form an item worth reckoning in the family expenses; nor need we aim at making the manufacture of iron exist, as a branch of national industry, upon the elementary condition of giving meat only once a week to its great mass of laborers, as Mr. Hewitt so tersely sums up the substantial state of affairs in France. But we should observe care-

fully the steps already accomplished in cheapening the production of iron, or, what is synonymous, the careful utilization of the utmost power men are capable of exerting over crude materials, to make the labor performed by every workman employed of sensible effect in accomplishing the final result, and, by carefully watching in what direction the observations already made and the principles already established are tending, see how they may be best made applicable to us and our country, that our magnificent natural resources may be made perfectly available, and the constantly increasing demand of our broad land be met from its own soil, and our own nation, instead of foreigners, permanently enriched by supplying it by the economical development of the treasures stored up beneath our feet.

What has been, and still is being accomplished in this direction, finds a partial barometer in this exhibition, a still more evident one in the rapid but wholesome growth of Troy, of Pittsburg, of Cleveland, and of the district about St. Louis, while, outside of towns, there is not a fertile farm in Pennsylvania which does not, by the high price put upon it, most powerfully indicate the advantages agricultural interests derive from the development of our mineral resources, and, simultaneously, point out the road Americans should wish to see America follow.

The statistics of the Lake Superior district will place vividly before you the most astonishing increase of the mineral development of our Northern border, within a little more than a decade of years; beginning with 1856, when iron ore was first mined there in any quantity, there were shipped 7,000 tons of ore, but not a ton of pig iron was then made there; in 1869, 633,238 tons of ore were shipped over the two railroads leading from that region, and 39,000 tons of iron were made; during these 13 years, 3,000-000 tons of ore, and 400,000 tons of pig iron have been brought from what, 20 years ago, was practically a wilderness. Still further West, the Northern Pacific Railroad will open up another region, where a similar history will be repeated. Missouri has already begun her race in the same direction of industry; the whole tier of Southern States only need complete restoration from the fever and delirium which began in 1861, and from which they are now convalescent, to pour out, from their northern frontier, such stores of mineral wealth as would make us gape with astonishment, had not constant employment of that faculty made wonder at any display of material resources in the United States almost impossible.

Notwithstanding my determination not to go beyond pig iron in treating my subject, I cannot forbear calling your attention to the surprising growth of our manufacture of rails, of which, 30 years ago, not a ton was made in America, the first rail having been rolled in 1843, while last year nearly 600,000 tons were made, more than half in Pennsylvania, and nearly 100,000 tons of it in New York, at Spuyten Duyvil, Troy, Rome, Syracuse, Elmira, and Buffalo, of a quality admitted to be far superior to the foreign rails generally brought here, and with which we are compelled to compete in price. The quality of our pig iron is also better than three-fourths of that made in England, yet the question of quality is usually practically ignored when discussing the question of sustaining, in America, the product of iron in any form.

The total supply of iron ores of all desirable qualities is practically inexhaustible. The heaviest known deposits, taking the country through, are almost untouched. In many of the easily accessible locations, where the deposits, originally worked, have been mined so deep as to make the ores too expensive for profitable working, new beds have been opened in immediate contiguity, so that no loss has been sustained, and in others some accidental circumstance or systematic exploration has developed new deposits which could be so much more cheaply worked as to cause the abandonment of the old mine, while yet the ore was as abundant as ever. I have a familiar acquaintance with a property within 2 hrs. ride of this city, which has been worked for more than a century, and which is so far from exhibiting signs of exhaustion, as to have yielded last year, as cheaply as ever, more than 80,000 tons of ore. A striking example of long continued yield are the mines in the Island of Elba, from which ore has been exported for more than 2,000 years, and which in 1867 yielded 60,000 tons of ore.

If the manufacture need not be limited from fear of exhausting ores and fuel, neither should there be any solicitude lest there be too much iron produced. The iron production of the world scarcely keeps pace with the augmented demand, and our country has never, since its political independence was achieved, made anything like the quantity necessary for its use, while the iron needed, per capita, is constantly increasing; so that to say that our make of iron is increasing faster than our population, and therefore it would perhaps be well to endeavor, indirectly, to check the growth of this industry, is, most emphatically, a fallacious course of argument. To compare very briefly our relative rate of consumption and production, let us glance for a moment at the metal required for rails, which absorbs the equivalent of half our make of pig iron. Since 1866, when we first fairly got breath after the close of the war, the demand for rails for new roads has increased about 10 per cent. per annum. Estimating the duration of rails at 10 years, which is certainly liberal, we have 10 per cent. more of the total quantity in use, required every year for repairs, in all an increase of 20 per cent. per annum; the American production of rails, in the same time, has increased 13 per cent. per annum, and in the make of pig iron there has been an average increase of less than 11 per cent.; showing that the manufacture of pig falls constantly behind the increased demand from the rail mills, and the manufacture of rails constantly behind the increased demand from the railroads.

As a mercantile adventure, it would perhaps be unbecoming in me to say that it don't pay to engage in the manufacture of iron, nor should I wish to convey the idea that we may not, some time, hope to see our iron-masters experiencing that prosperity which has made some of the iron-workers in Europe the wealthiest men in their respective countries; but I hazard nothing in saying that except during the war, when every business paid extraordinary profits, if there be fairly considered the capital employed and the heavy risks necessarily taken, the production of pig iron has never been largely profitable in the United States; and I desire here to say in reference to a statement, extensively copied by various newspapers, that a certain iron-work on the Hudson had paid 40 per cent. dividends, that many years before 1861 it paid *no* dividends, and finally, recently paid 40 per cent.—not on the capital actually employed, but, by the aid of its real estate, upon the original capital, which had lain a long time without yielding any return to those originally risking it. We may not hope for any sudden change from the generally very small profits furnaces are now making; but gradually, as labor becomes dearer in Europe, and capital cheaper here; as we, partially because of these changes lessening the risk of building extensive works, put up large furnaces, and are not compelled to adopt some inferior details of manufacture, because the best ones are, in the beginning, more costly; as we are able to command and gain the habit of employing the best scientific aids to our practical furnacemen; as by experience, also, we learn the best way of employing our ores, not staying away from the water until we know how to swim, lest we be always dependent on the boat some one else may or may not be willing to spare us, but continuing our efforts to learn, though at the expense of occasionally going under the surface, we shall finally achieve the success which, as thorough Americans, no less than enthusiastic iron-masters, we aim at, when we can not only profitably supply the heaviest demands of the home market, but be enabled to reverse our present position, and export, instead of importing this really precious metal.

Rumor states that the African diamonds are no better than the South African wines.

Buenos Ayres.—The Argentine Legislature has passed a law for securing an effective drainage, sewerage, paving, and water supply for Buenos Ayres. The works are to be carried out by a committee, with the assistance of an experienced and competent engineer. A credit of £60,000 per annum has been opened for the prosecution of the various undertakings proposed to be taken in hand; but unless a larger credit is authorized, the works contemplated will be 16 yrs. on hand, as their cost has been estimated by Mr. Coghlan at about £950,000.

ANCIENT EGYPTIAN ENGINEERING AND MODERN WAREHOUSES.

From "The Mechanics' Magazine."

In old days architecture and engineering were one; in these modern days they are, by our system of division of labor, separate. Architecture is one thing, engineering is another. The Lambeth Suspension Bridge is an example of pure and simple engineering, *i. e.*, pure and simple construction without the addition of any element of fine art; and the great question therefore is—and it is one of the most important of all modern questions, for it includes so much—what is the value of pure construction as an element in art, and how best may it be improved, and is it to be improved by the addition of forms from the antique and the past, or is it to be verified by the addition, and what kind of addition, of anything from things as they now exist, and as they pass around us? This is the art question of the time, and there surely can be no more interesting subject to the student of engineering, for must he not naturally desire to influence if possible the art as it appears in construction of the age he lives in? To help him to do this we propose to offer a few hints on a new method of wo k, and to contrast it with the present and past systems of work.

Before we do this it will be necessary that there be some definite notion of the old system of work, or in other words of the old architectures, which were, indeed, nothing more than the construction of the times, ornamented by the art peculiar to those who employed that construction, whatever it may have been, and this it will be found was all got without exception from the living art and nature of each special country and age and people. It must at the same time be always borne in mind that not only has the art as fine art and method of ornament changed from age to age, but that the systems of construction have changed too. Before the invention or accidential discovery of the arch of course it could not be employed, and it would be not a little curious nowadays to see a town or city entirely built without any use whatever of arch construction; but time was when the absence of the arch was universal, no arch forms were anywhere visible, all construction and covering in was by means of straight beams or "lintels." It will be convenient to bear this in mind as a not inapt division of architecture into two divisions or orders—the arch order and the lintel order. This simple division will be found to conduce, if kept in mind, to clearness of apprehension.

We do not propose to go into all the several phases which these two systems of architectural construction have passed through in the different countries in which they have appeared and been practised; but we must, to make things clear, and to show how much there is yet for a future generation if not for the present to do, cite one or two examples of one or two of them, and then hint, as we go on, at the uses which might have been made of such examples by modern engineers had they but have known of them. Whatever may have been the difference between the ancient and modern systems of doing work, of one thing there can be no doubt, that at no time in the world's history has there been more building than at the present time, or greater opportunities of doing great things and impressing on such building some stamp of modern and nineteenth century life, and of conveying to distant times some material idea of what our present life is like, and what it is worth as contrasted with the life and ways of Athens or Rome, of Persepolis or Babylon, or of the great cities and towns of France and Germany in the middle ages, or of our country in bygone days.

To get a tolerably clear idea, then, of such an architecture or system of construction as that of ancient Egypt we must first bear in mind that all there was of it, whether much or little, was Egyptian, and nothing else—there was no borrowing possible, it was all the work of the people themselves—and that all that we now see of Egyptian art and architecture was, for anything that we can tell or see, entirely their own, and their own invention. How long it took to grow up from its beginnings and develop itself is indeed a difficult question and perhaps impossible to answer; but of this we are quite certain, that it was purely the Egyptian's own work and his only, and did not come of any foreign source.

Now this, if we come to consider it a moment and without prejudice, is a truly wonderful thing, for how any one single nation, however great it may have been, could have done such marvellous works without foreign help and by themselves is indeed surprising, when we consider how much we nowadays owe to foreign help, and but think for a moment where we should be without it. Fancy for an instant what would the modern architect or engineer or even common house builder do nowadays without precedent of any kind, with all his materials on the ground and workmen ready and able to work, but he himself without book guides, or in other words foreign help, or, in still plainer words, without bygone architectural and artistic forms and methods of work to go by, whether Classic or Gothic. What would the modern man do? No one can answer this question, nor can anyone see his way to any sort of answer to it. But this was the state exactly of the old Egyptian engineer; he had nothing to go by but what he had in himself, what there was about him in actual life, and the dead materials on the ground waiting to be wrought into the form and semblance of something, and to be impressed with some special character.

And again—and this must not be forgotten—the old Egyptian had in our sense of the word no science, none of that science which is now altering the very face of the globe itself. He quarried the stone blocks which afterwards formed the walls of his temple, but he knew nothing of where they originally came from, or how they were primitively formed. He knew nothing of the "mechanics of engineering," of the steam engine, or of any of those wonderful forces which now form the study of so many, and which puzzle so many more, and a knowledge of whose action will in the future change the very thoughts of men, their aspirations, and their hopes. He knew nothing but of the materials dug from the earth, the very simplest laws of construction, or rather practical methods of construction, and the art which had grown up in his own country, and which was peculiarly his own. He knew also the necessity of employing personally those who were gifted with the power of impressing on the unformed and rough materials the proofs of their own individual artistic skill. Nothing could possibly be simpler or more self-evident, and it is not a little surprising and certainly not less instructive to compare the work of the old Egyptian thus simply provided, with that of our modern railway works. There is, as we all know, nothing in modern times so large and impressive as the works, whether of building or civil engineering to be found in and about railways. They are the only things that can for a moment compare in extent and magnitude with the temples of the ancient world. All our modern churches and chapels and the buildings connected with them, all our house or even palace building is but poor work, as mere building, compared with Egyptian temple architecture and engineering; and the wonder is how such work could have been accomplished with the slender mechanical means which they who built them possessed. It would puzzle even our civil engineers to raise and put steadily in their places, and without breakage, such vast masses of stone as were necessary to reach from column to column in the Egyptian temple architecture; and still more would it perplex them to fit them so nicely into their places, and with so fine a mortar joint, and beyond them altogether to so do the work as to make allowances for the "eye line" as it is termed, that is, to so curve the stone as to give it its true proportion to the eye, and to make of the mere line of a rule an artistic one. With such vast masses of stone to deal with, this is indeed noteworthy. We have nothing like it, or indeed any approach to it, and we mention it to show how little of anything that can truthfully be called an advance or improvement has taken place during the many ages which have elapsed since the days of the Pharaohs! And all this be it observed without our mechanical appliances and scientific apparatus and cranes and steam engines.

We have mentioned those works to be found in London, the works of the civil engineer, which are, as we think, remarkable for the absence of architecture or fine art borrowed from the past, and, so to speak, fixed on to it as by afterthought; for it is in such works that we may be said to find ourselves in the precise position of the old Egyptian engineer, we are fairly left to ourselves without precedent or anything to go by to make or create art or architecture as it is called. We

have named several of these works, and we might add to them the great blocks of warehouses which line the banks of the Thames, particularly those newly built below bridge on the Surrey side of it. Any one going through the long lane called Shad Thames may see what modern men can do with mere bulk, for some of these warehouses are of the most solid materials, and some 80 ft., 90 ft., or 100 ft. high; the walls of great thickness, the floors of solid and massive timbers, and the roofs fireproof and of the most improved construction. No expense has been spared, yet who will venture to say that this long line of tall buildings, massive as they are, have any sort or kind of dignity or art, or architecture, or beauty, or even interest in them? They are simply four walls with windows and roof, built up to hold goods, yet by altering a little the main lines of them, and the direction of their roofs, and giving a little thought to the windows, these huge buildings might have been made really artistic, and the whole line of street—and we still refer especially to the narrow street bordering the river to Shad Thames—might have rivalled in dignity and interest any thing to be found in countries whose history is passed away, but which have left so many memorials of their power over the rough materials which nature provided for them. We mention these warehouses in addition to railway works of which indeed they are sometimes a part, first, bebecause they are the work for the most part of the civil engineer; and secondly and chiefly, because they are not architecturally ornamented, nor has any effort been made to make them look like palaces by ornamenting them with architectural details taken from Venetian palace architecture, or from French cathedrals or street mansions. In Egypt, it may be observed in passing, the house architecture would seem to have been of the simplest kind. The great efforts of the engineer and architect were confined to the palace, temples, and pyramids, and river terraces, so that the art of old Egypt was of a very democratic character indeed, and employed for the good of all, and open to the eyesight of everybody. In our more advanced and improved days the poor public see but little of fine art, for it is all in the interior of our buildings, and those buildings are almost always private property, and so visible to none but their owners. The Lothairs of modernism do not care to exhibit their art splendor!

LOCOMOTIVE IMPROVEMENT.

From "The Engineer."

In our last impression we endeavored to show that no improvement in the comparative efficiency of the locomotive boiler can be expected as long as the existing type is retained in its integrity. This argument is based on the fact that the modern boiler being no better than the boiler of 10, 15, or 20 years ago, it is hopeless to expect any further improvement. It is, of course, just possible that the able engineers who have devoted their attention to designing locomotives have one and all suffered those features in which improvement could have been effected to escape them; but this theory is to the last degree improbable. We hold, therefore, to our statement that unless some radical change is introduced in the construction or working of locomotive boilers, we are not justified in reckoning on any better result than an average evaporation of some $6\frac{3}{4}$ or 7 lbs. of water per lb. of coal burned. What the radical change in construction and working is to be we are unable to say positively, but we can at least indicate the nature of the alterations which are likely to prove advantageous; and it is to be borne in mind that although these alterations may be very radical and thorough in their character, it does not necessarily follow that the general characteristics of the boiler, at least as regards external form, need undergo much change.

In former articles we have explained the points in which the ordinary portable engine boiler constructed by agricultural engineers is superior to the vertical boiler, but the statements we have made with regard to portable boilers will not hold

good for the locomotive boiler. We have deprecated to a certain extent any innovation on ordinary portable boiler practice, but we cannot deprecate innovation on ordinary locomotive practice. The principal causes of the low economical efficiency of the locomotive boiler are inefficiency of surface, want of circulation, and rapidity of draught. The tubes in locomotives are packed so close that the presence of good circulation is almost out of the question; but the tubes in portable boilers are so widely spaced that the circulation ought to be, and doubtless is, much more efficient. As regards the second point the draught is much less energetic in portable than in locomotive engines; and for any given length of flue the products of combustion are suffered to remain a longer time in contact with the iron. Lastly, the temperature of the water in portables being much lower than in locomotives, an element of economy is secured in the first which is lacking in the latter. We shall not extend our comparison between two boilers so apparently similar in type, but totally dissimilar in working conditions. It will, we think, be found, on close examination of every point connected with the two boilers, that the similarity between them is apparent only; and that it is simply impossible to argue from the results obtained with one, what results ought to be obtained with the other. We may, therefore, dismiss the portable boiler for the present. We have spoken of it here only to guard ourselves against the possibility of being accused of inconsistency by those who think proper to read these articles with those which appeared in our impressions for July 29th and August 5th, 1870.

Before we can hope to improve upon the existing locomotive boiler, it is absolutely essential that we should thoroughly comprehend the nature of the defects which it is proposed to eliminate. What these are we have just stated in general terms. But many people speak of the phenomena of defective circulation, inefficient surface, and forced draught, without possessing any accurate perception of the way in which these defects really operate for evil. We shall endeavor to place these matters in the clearest possible light, and to draw some conclusions which, at the same time that they are, as we believe, unavoidable, will not fail to suggest a means of improving the evaporative economical efficiency of the locomotive boiler.

First, as regards inefficiency of surface. This simply means that the tubes and fire-box plates become coated with scale, which, being composed of sulphate of lime and other salts, and earthy matters, is a very bad conductor of heat. The effect of the presence of this deposit on the tubes and fire-box is that less heat can escape in a given time from the products of combustion into the water than would be the case if the deposit were not present. In effect, deposit virtually reduces the length of the tubes and diminishes the size of the fire-box. It is not certain, however, that deposit in moderate quantity diminishes the *actual* efficiency of a steam boiler. Peclet has shown that iron boilers evaporate just as much as copper boilers in a given time, although the conductivity of copper is nearly double that of iron, because, to use Peclet's own words, "When the thickness of a metal is augmented, its conductivity is diminished, but the temperature of its external surface is augmented in just the same proportion." "It is believed that, as the quantity of heat transmitted augments with the temperature of the exterior surface, the influence of the kind and thickness of the metal is very trifling." Peclet then goes on to furnish proofs in support of this belief, for which we must refer our readers to Peclet's "*Traité de la Chaleur*," *tome premier*. Again it must not be forgotten that the quantity of heat passed in a given time through a plate depends much very much more on its power of absorption and emission than on its power of conducting. The precise meaning of this statement will be found very clearly set forth in a paper on "Water-tube Boilers" read before the Society of Engineers on the 6th of May, 1867.

Now we do know that deposit directly affects the conducting power of a tube, but we do not know whether deposit increases or diminishes its emissive power. It is possible that a coated surface will emit more heat than a plain, smooth metal surface, because the coat of deposit is rough, and the roughness may aid the formation of steam like the coil of silver wire on the little bits of pure coke used by chemists to obtain equal

ebullition in laboratory experiments. But whether it does or does not, it is certain that the direct effect of anything more than the thinnest possible coating of deposit operates prejudicially. It does not follow that the actual energy of the boiler as a steam generator will fall off. The temperature in the tubes is augmented and the same quantity of heat finds its way per second or per minute into the boiler, but this result is only obtained by harder firing; in other words, by burning more coal. The dirtier the tubes and fire-box the higher will be the temperature in the smoke-box, and of course the greater the waste.

And here it will be well to notice an objection constantly urged by those who believe in the excellence of the locomotive boiler, which may be thus stated: "The boiler can only be uneconomical by wasting heat, but if it wastes heat, that heat will be found in the smoke box; it will manifest its presence in the high temperature of the escaping gases. But there is not a high temperature in the smoke-box, therefore heat is not wasted." This is a very logical proposition, which breaks down only at the end. No one knows accurately what the temperature is in the smoke-box. So long as an engine is not heavily taxed and the draught is moderate, it is indisputable that the temperature, especially if the tubes be long and small, is low; and there can be no question that engines moderately loaded and running at low speed evaporate more water per pound of coal, provided combustion be perfect, than does an express engine careering across country at 50 miles an hour with 10 or a dozen heavy carriages behind it. The boiler quickly falls off in efficiency as the quantity of coal burned increases, and this is no doubt one reason why the cost of transport increases so rapidly in proportion to the speed, albeit it is one which has not received half the attention it deserves. But to return to facts connected with smoke-box temperature: Stephenson's experiments made in the neighborhood of Derby, in 1843, showed that in the ordinary locomotives then in use the temperature in the smoke-box was great enough to drive zinc off in vapor; and this metal requires a temperature of not less than 800 deg. to melt it. As a result of these experiments, Stephenson introduced his well-known "long boiler" locomotives, many of which are still running on the Great Eastern and other railways, with tubes nearly 14 ft. long. The evidence usually adduced in opposition to the idea that a high temperature exists in the smoke-box, is based on the fact that the black paint put on outside lasts a long time; but this is not good evidence, because, first, the inside of the box is always lined with a thick coat of soot, which is an admirable non-conductor; and, in the second place, the smoke-box plates are exposed to the action of a violent current of air, which increases in its effect with the speed of the engine. Besides this, there is little doubt but that the products of combustion operated upon by a powerful draught rush direct from the tubes to the chimney, and are, therefore, drawn away from the sides and front of the smoke-box, which is always some inches larger than the barrel of the boiler. The wonder is, considering the cooling effect of the external air, that the paint is ever burned off a smoke-box at all. But it is none the less likely that the temperature within frequently reaches, or perhaps exceeds, 800 deg., or at least 450 deg. more than the water within the boiler. As the draught is dependent on the exhaust, and not on the temperature of the escaping gases, as in stationary boilers, there is no reason why the temperature in the smoke-box should exceed that in the boiler. The only method of even approximately obtaining that result as yet used by engineers consists in lengthening the tubes; but this plan is always attended with the disadvantage of rendering a smaller blast pipe—and consequently an increased back pressure—necessary to maintain the draught. It remains to be seen whether other remedies may prove more effectual.

It is to be regretted that no accurate experiments have been made to furnish us with data as to the precise loss of efficiency due to the gradual accumulation of deposit on locomotive heating surfaces, but enough is known to prove conclusively that a great point would be gained if it were possible so to construct the boiler that either no deposit could form, or that the boiler could be taken to pieces and thoroughly cleaned, say, once a year. Our readers will, we think, admit unanimously that the presence of either one

or both of these conditions in any boiler proposed as a substitute for the ordinary locomotive boiler would be a strong point in its favor. We may have something more to say about this further on; just now we must turn to the consideration of the second defect in the existing boiler—want of circulation. About the rapidity of escape of the products of combustion little more need be said than we have stated already. It is impossible to reduce it without augmenting calorimeter, which cannot be done under existing arrangements. Whether it can be done at all with success, or whether it is necessary it should be done, are points the consideration of which we shall reserve for the moment. As regards the question of circulation in locomotive boilers, it is difficult to speak without using as an illustration of our meaning an explanation of what appears to us to be the only available method of making it really efficient, and this deserves an article to itself. However, we may say something which will lead up to the article to which we refer.

Most engineers admit freely enough that the circulation in locomotives is not what it ought to be. Yet in practice we find them cramming their boilers as full as they will hold with tubes. Half-inch spaces are by no means uncommon, and some French engineers have stowed their tubes but .44 of an inch asunder. We have heard it argued, and by good authorities, too, that the reason why locomotives so made are not economical and burn their tubes, is that there is not water enough in contact with each tube—in other words, that the thickness of $\frac{1}{4}$ of an inch of water is not enough to take up all the heat passed by the tube. No greater mistake could be made. The true objection to the close stowing of tubes lies in the fact that the steam as it is formed on the tube surface cannot get away, and as a result it is steam, not water, that is in contact with the metal. Water is an excessively bad conductor of heat, but is perhaps the most powerful absorber of heat known when properly used. The close stowing of the tubes would matter nothing if only we could get rid of the steam, but this we cannot do so long as we dispose tubes in such a way that the area of escape is contracted and interrupted to the least degree, while no sufficient means are provided for sweeping the bubbles of steam off the tubes. A strict analogy exists between the boilers and condensers, and it may be taken as proved that *within certain limits* the quantity of steam which can be condensed by a given surface is altogether independent of that surface, and absolutely dependent on the quantity of cold water brought in contact with it in a given time. In the case of boilers much the same truth holds good. If we take a thin metal pipe and pass it through the fiercest furnace which it is possible to get, that tube cannot be over-heated, provided enough water is sent through it in any given time. Extension of heating surface is neither more nor less than a substitute for defective circulation and absorption. To put this more plainly: If we have two plates of metal, each exposed on one side to the same temperature, and each in contact with a given quantity of water on the other side, then by doubling the quantity of water brought into contact with one we may practically double the efficiency of that surface as compared with the other. It is to be borne in mind that if the original quantity of water in contact with each plate is great enough to absorb all the heat it can have, then of course our proposition will not hold good; but this is not the case with locomotive boilers. The tubes there are in very much the condition of a saucepan on a fierce fire with but a spoonful of water in it, not sufficient evenly to cover the whole bottom. If this spoonful be kept constantly renewed as evaporation goes on, still the saucepan bottom will not generate as much steam or do as much work as would the bottom of another saucepan on which a jet of water continually impinged. The film of water might be of the same thickness in both cases, but in the latter all the steam bubbles would be swept away, while in the former they would continually intervene to prevent true contact between the metal and the water. It is not the deficiency of water, but the presence of steam between and in contact with the tubes, that impairs the efficiency of the locomotive boiler with close stowed tubes. If only we could dispose of the steam, we might put our tubes $\frac{1}{8}$ of an inch asunder, provided we could command means of clearing the tubes of deposit. It is simply impossible, however, to get rid of

the steam as fast as it is formed in locomotives with close-packed tubes. How, then, is the objection to be got over? The answer is this, and embodies so important a proposition that we put it in italics: *Do not allow any steam to be formed between the tubes;* and we shall put this in more general terms by stating that *every boiler, locomotive or other, in which it is intended that the heating surface shall possess a maximum efficiency, must confine its functions to the heating of water, not to the direct production of steam.* Under no circumstances should steam be directly produced by any heating surface, unless means are provided for removing that steam immediately. We propose to show, in a third article, how it is possible in practice to apply principles, the soundness of which was recognized in an indistinct and misty kind of way many years ago.

BOMBAY TO CALCUTTA BY RAIL.

The following from the "Times'" correspondent, dated Bombay, Sept. 7, gives an interesting description of the journey across India by railway :—

I have just made a rapid run across India, from Calcutta to Bombay, in 62 hrs. The time occupied by the mail trains at present is 68 hrs., but in a few weeks the opening of the Chord line of the East Indian Railway will reduce the time to 64 —a little more than 2¼ days. All the arrangements are admirable. On both of the Great Indian and East Indian lines the mail train runs at 25 miles an hour with great punctuality. The refreshment rooms are wonderful for India, but the careful traveller can always make himself independent of them. The sleeping carriages for the first-class on both lines are comfortable enough, but those of the Great Indian are superior to the other lines. Were the second-class carriages of the East Indian Railway Company half as convenient as those of the Bombay line, I would recommend all gentlemen at least to use them. They are cooler than the first-class, and the charge is just one half. From Bombay to Calcutta the first-class fair is about £15, and the second-class half of that, but the charge for luggage is heavy. The great rush of passengers through Bombay to all parts of India is just beginning, and, on the whole, the railway companies are prepared for it. Even at present ladies may travel comfortably, and in India one soon becomes accustomed to long journeys. But in a few months American palace cars will be placed on both lines, when the journey will be almost luxurious for those who care to pay a slight addition to the first-class fare. Passengers landing at Bombay in the morning may take the mail train at noon, thus avoiding hotel expenses. Those who must spend a night in Bombay or desire to see the island will find improved hotels. A gigantic iron structure is nearly finished on the Esplanade, having cost £70,000 already. It stands midway between the Apollo landing pier and the Boree Bunder terminus, and is in the centre of the new city, of which it is hardly worthy. All train arrangements have now to be made to avoid traffic on the Thull Ghaut at night. There is little risk, but one serious accident has already occurred. In the library and reading-rooms of the Asiatic Society, in the Town Hall, and in the fine institute which bears the name of the Jew merchant prince, Sassoon, near the hotel, the visitor will find all the most recent periodical literature, both Indian and European.

I was enabled to anticipate the opening of the Chord line, and to run along it at the rate of 30 miles an hour, by the courtesy of Mr. Perry, of the contractors' firm of Messrs. Brassey, Wythes & Perry. There is no reason, so far as the contractors are concerned, why the line should not have been opened months ago. It is in a much more forward state than the portions on either side which the East Indian Railway Company are doubling, and even than the Jubbulpore section of the Great Indian line, which Lord Mayo and the Duke of Edinburgh formally opened last March. The main line follows the tedious detour of the Ganges, in order to accommodate the traffic of the valley and its great cities. The Chord line cuts off a distance of 3 hrs. in the journey between Calcutta and Patna. It leaves the Rancegunge coal branch, henceforth to be

the main line, at Seetarapore, and joins the old main line, at Lukeeserai below Patna. The whole distance is 147 miles, of which 123 are trunk, and the rest form a branch to the fine coal fields of Kerhurbalee, which the East Indian Railway Company are to work for their own supply. Messrs. Brassey, Wythes & Perry obtained the contract for £1,250,000 sterling, the Company to supply the permanent way.

The total cost of the line will probably not exceed £13,000 a mile, although it has been laid in a difficult, rocky country, comparatively destitute of population. The line should have been opened at the beginning of this year, and Lord Lawrence offered a bonus for its more speedy completion. But the land was not made over for 8 months after the beginning of 1866, there was no material for bricks, and the railway company have in many instances delayed to supply the permanent way. The marvel is that the line has been finished so soon in the face of such obstacles, physical and administrative. Almost all the labor had to be imported, cholera more than once scattered the gangs, and tigers carried off many a workman in the jungle country. The works display the finest and heaviest rock cutting in Eastern India, almost worthy to be ranked with that of the Thull and Bhore Ghauts in the Bombay Presidency. Of the 123 miles of trunk line no fewer than 40 consist of deep rock cutting. Leaving Seetarampore on the way to Bombay, the country differs little from the undulating coal deposits of Raneegunge till the first three stations of Meeja, Jamtara, and Seetacotta are passed. Soon we approach the heavy embankments and cross the fine bridges which span the Jyntea and the Puttro tributaries of the Adjar river, now swollen by the season's rain. To the north the Beerbhoom hills, the last outcrop of the Vindhya range which crosses India, tower aloft. To the south is the grand trunk road, with the little sanitarium of Parisnath, sacred to the Jains, rising suddenly from the jungly plain. We reach Mudoopore, the changing station for the Kurhurbalee coal fields, 24 miles off, and for Parisnath, 16 miles to the south of the branch terminus. It is to be regretted that so little has been done at Kurhurbalee in raising coal or preparing the shafts and machinery. Until a railway has been opened to Darjeeling, it is likely that this part of the country, and especially Parisnath, will become a retreat for invalids and holiday-makers from Calcutta as Matheran is from Bombay. We are now in the Santhal country, the scene first of rebellion, provoked by our own folly, and then of mutiny. We cross the Adjar on a bridge of 10 spans of 84 ft., with piers resting on rock 40 ft. below the bed of the river, pass Rohinee, where Macdonald fell a victim to the native cavalry, and reach Byjuath, 3 miles from the sacred shrine of Deoghur, to which so many pilgrims flock. What a change has passed over the country from Rajmahal to Deoghur since the local rebellion of 1856! Sir George Yule's patriarchal administration, followed by the two railways, has delivered the simple Santhals from the bonds of the Bengalee usurer, although they still consider it both prudent as a precaution against years of famine and a sign of respectability to keep their names on the money-lender's books for a few rupees.

Cultivation has greatly extended in the last few years, for the people are becoming comparatively wealthy, and they have now found markets for their produce. They are crying for schools, too, and the missionaries are fast converting whole villages of drunken and unchaste peasants into good Christians. We leave the picturesque Santhal country for the plains of Monghyr by the Nargunjoo Pass, a magnificent cutting of 5 miles, on which for 4 years some 5,000 men have been daily engaged, and 240 lbs. of powder have been daily used. At this season the whole pass resounds with mimic waterfalls. It is green from the summit, and ends in a pretty lake, which the engineers are turning to good use. We soon dash through the changing station of Newadee, through Mulleepore and Etone, to Lukeeserai, and catch the mail train, which has been so much longer on the road. It is not probable that this Chord line will add to the shareholders' dividends for a long time, if, indeed, it does not diminish them at first. But it has opened up a fine country teeming with mineral wealth and with endless agricultural resources. The line has been as solidly constructed as any in India, for at the close of a season of heavy rain the new embankments and bridges were perfect.

RELATIVE ECONOMY OF COFFER-DAMS.

From "The Mechanics' Magazine."

Notwithstanding that timber has for some time been almost totally superseded by iron in all works partaking of a permanent character, yet the older material is still extensively used in all those of a temporary nature. Among the latter the three largest examples are to be found in scaffolding, staging, and centring for bridges and coffer-dams. A practical illustration of the first is to be seen, or rather was a few months ago, on the site of St. Thomas's Hospital. The new bridge at Blackfriars afforded a splendid specimen of the second, and the walls of the Thames Embankment fully proved to what an extent the third could be carried. Many persons who observe in a cursory manner only the bewildering array of huge balks of timber, half timbers, stays, struts, and braces of every size and description that constitute the *tout ensemble* of a large temporary wooden structure, come to the conclusion that there is very little method or system in the arrangement. But upon a closer examination, especially if that examination be conducted by a professional man whose eye is capable of discriminating between multiplicity and confusion, the whole massing together of the timbers will prove to be in accordance with well-known scientific laws of combination. Each particular component part will be found to have its own especial duty to perform, and in the accurate allotment of these several duties and in the proper proportioning of the various parts, lies the whole economy of the temporary structure. When constructed in a scientific manner a very little timber will go a long way, whereas a whole forest might in some instances be exhausted without yielding the strength and rigidity so much required. It is not the quantity of timber employed that constitutes the security of the structure, but the positions in which the various uprights, together with the ties and cross bracing, are placed. Very frequently a large amount of timber is completely sacrificed by being placed where it is of little or no use, while the safety of the structure is jeopardized by the absence of it at other points where it is urgently needed. If the timber used in temporary works be divided into the three classes of vertical, horizontal, and inclined, the largest sticks will generally be included under the former two. The inclined pieces comprise the individual components of the bracing, consisting of struts and ties, which from the different manner in which they are affected by the strains, can be composed of smaller or half timbers. When the temporary work has any pretension to magnitude the vertical and horizontal beams are mostly all whole timbers. They are generaly of as large a scantling as can be obtained for the purpose. It is always desirable to procure the balks for the uprights in one length when possible. When this cannot be done they must of course be scarfed.

The relative economy of substituting iron for timber in temporary works has been very much discussed among engineers and contractors, but as yet no decisive conclusion has been arrived at. There are so many points to be considered, and the instances which occur in actual practice present so many features of diversity, that the application of a general rule appears to be well nigh impossible. In the first place, the economy does not depend upon the fulfilment of one, but of several conditions. There is the first cost of the two materials to be taken into consideration, then the cost of erection, of maintenance, and subsequently when the temporary means have accomplished their work, that of removal and ultimate disposal. It is rare that a case would happen in which all these contingencies would tell favorably with respect to one material and prejudicially to another. If that were the state of affairs the question would have been determined long ago, and there would not be the slightest necessity for entering upon it. Our comparison at present rests between the adoption of iron, timber, or other materials for coffer-dams. Everyone is acquainted with the construction of an ordinary timber dam. That used for the Thames Embankment will serve as an example, and there are probably but very few of the inhabitants of the metropolis who have not, at some time or other, had an opportunity of inspecting it, either from one of the bridges spanning the river or from a boat on the

river. As a full description of the dam on the Middlesex side of the Thames is to be found in our columns of last week, we shall not recapitulate, except when necessary for the purpose of illustrating our comparison. There are four principal methods which may be employed in the construction of dams. Firstly, they may be made altogether of earth and such excavated materials and *debris* as can be procured near at hand. This is unquestionably the cheapest kind of dam that can be constructed, provided always that the material can be obtained within a moderate distance from the site of the work. Unfortunately this condition is very often quite impossible of fulfilment, and the difficulty of so doing is enhanced by the fact that a dam of this description requires a larger amount of cubical material than any other. It is, cubically considered, the largest dam of any, as it has nothing to depend upon for support but its own inherent weight and stability. For permanent works such as the Thames Embankment and reclamation of land from the sea, this kind of dam is admirably adapted, but for the reasons given it is not suitable for works of a temporary character. The large area of ground it would occupy would be a serious obstacle to contend against. There is another feature which is also disadvantageous to it; it is that in order to bestow upon it those attributes of strength and solidity which must necessarily belong to it, a comparatively long time must be occupied in its construction. It is a dam that must be made up very slowly. In fact, the slower the better. The more time afforded for the incorporation and consolidation of the separate layers successively superimposed, the more firm and consistent is the whole rendered. It is needless to point out that a dam of this description is an impossibility in situations similar to that of the Thames Embankment. The material could not be obtained, the area of ground on which to build it was not procurable, and the necessary time could not be afforded. Under these circumstances it was imperative to adopt some other method of construction.

The second description of dam which we propose to consider is that best known and employed, it may be said, from time immemorial. It consists of a double row of piles, enclosing a puddle wall in the intervening space, and shored and strutted with timber as necessity may require. In this case less ground is needed than in the former, and also the earth is limited to the supply necessary to form the puddle. But although the quantity of the earth is thus very much reduced, the quality demanded is of a very superior kind. Common excavated stuff will not answer. Good clay must be obtained, or the dam will fail in the most essential point—that is, it will not be water-tight. Those who are aware what an expensive item pumping constitutes in all similar temporary undertakings will be able to judge of the importance of this particular. In spite of all precautions leakage is certain to ensue from the shrinking and contraction of the puddle, as well as from other causes. At the Thames Embankment dam pumping to a greater or less extent was carried on until the water had risen to 6 ft. above low-water mark. The maximum volume raised per minute amounted to 1200 gallons, and the minimum to about half that quantity. In all dams of this kind the introduction of the puddle element is a serious source of expense, for if we select, as another example, one in which the piles are replaced by earthen slopes, while the puddle and half timber shoring are retained, there is very little saving effected, and under certain conditions there would be none at all. Classing all dams under the heads of puddle and non-puddle dams there remains to be considered that description in which the combined effect of the ordinary piles and puddle is obtained by the employment of either wrought or cast iron caissons, that is, by the substitution of iron for timber. Some amount of timber will be required for the shoring, which may be regarded as common to both methods. The use of the caissons obviates the necessity for the somewhat precarious labor of driving piles, and the dredging can be carried on with equal, if not with greater facility. Unless ordered beforehand there is more difficulty in obtaining caissons than piles, as there is a perpetual demand for timber, whereas the former are not yet employed to an extent that justifies their being kept in stock. In certain situations we should give the preference, on the score of economy, to the caisson system.

There is one point which, in comparisons of this nature, is invariably overlooked and disregarded; it is that the different estimates cease with the erection of the temporary work. This is only doing the thing by halves. The removal of a dam and the ultimate disposal of the materials used in its construction is intimately connected with the whole question of its relative economy, and will frequently serve to turn the scale in the very opposite direction to that to which it would incline when the comparison is based on the former calculation alone. So far as dams constructed wholly of earth are concerned, the cost of their removal will be nearly equivalent to that of their erection. If there are no hollows in the vicinity to be filled up, and the material cannot be shifted into the excavation whence it was originally taken, all further consideration of it may be abandoned. Similarly with puddle dams, some provision must be made for running it to spoil somewhere, or re-utilizing it in some remunerative manner. The great plea put forward by the advocates of the caisson system is that the caissons can be used over and over again, as they are not in any wise injured or deteriorated by their temporary duties. Theoretically this assertion is correct, but it is nevertheless one thing to prove that a material can be used and another to use it. Unless a use can be found for it the mere possibility of employing it is of little avail. If a contractor had a succession of works on hand requiring the construction of temporary dams, so that as soon as one had done its duty there was an immediate demand for it elsewhere, iron caissons would prove invaluable to him. But this is never, or at least very rarely, the case, so that under ordinary circumstances the caissons might lie idle, especially in the present famishing condition of the profession, for years. A glance at the collection of plant arranged for sale by auction on the Embankment near Waterloo Bridge will indicate that iron caissons are not in such request as to cause them to prove very profitable for re-selling. Still it may be urged that the caissons can be utilized, whereas the timber used in a dam cannot. This latter statement is not altogether quite valid. It is true that as the piles have to be cut off not very far from the ground line instead of being drawn, the most valuable part of the timber is lost, as the remainder is a good deal damaged by bolt holes, straps, and the necessary fastenings. But it is a mistake to suppose that on this account it is altogether profitless. Most of it is of large scantling and in long lengths, and is always available for cutting up, and so long as it is sound in quality there is generally a market for it. There is no necessity for it remaining, similar to the caissons, long on the contractor's hands. If he cannot use it himself he will find plenty who can, and be glad to get it at the price. Second-hand timber of this description, if in fair condition, is worth a shilling per cube ft., or very nearly so. In selecting the particular description of dam to be used for any work, the details should be left to the contractor, subject to the approval of the engineer, as the former is the best judge of that which will turn out the most economical construction upon the whole. It is a very unwise proceeding to insist upon the contractor adhering to any especial means for accomplishing his own task. So long as he does accomplish the permanent work in a satisfactory manner and according to the specification, he should be left at perfect liberty to steer his own course, and be acquitted or condemned, not in the means, but in the end. No contractor objects to the most vigilant superintendence of the engineer, but he does decidedly object to the least officiousness or attempt at meddling with either the methods he pursues or the men he employs.

The Brooklyn Caisson of the East River Bridge reached its final resting place on the 21st of December. The lower edge is now 45 ft. below mean high water.

Steam Dummies are used on the elevated railway in Greenwich street, instead of the endless rope heretofore employed The success of the present experiment is not yet assured.

By a law, approved July 8, 1870, foreign trade marks and designs are protected in the United States.

THE RECENT DEVELOPMENTS OF COSMICAL PHYSICS.*

* Extracted from a Lecture delivered at Owens College, Manchester, introductory to the Session 1870-71, by Professor Balfour Stewart, LL.D., F. R. S.

From "Nature."

There are two conflicting theories with regard to education. The extreme partisans of one of these would have us believe that the great object of education is not so much to inform as to discipline the mind; the subject taught in a seminary may not in itself increase the student's real knowle·lge, yet if it tend to discipline his mind, it has proved its value in their eyes as a branch of education.

According to the upholders of this theory, our object in going to school is to leave it with a mind enlarged in its capacity for acquiring knowlege rather than stored with knowledge itself; having trained the soldier well they would send him without scruple into the enemy's country, not only to fight his own way but to find his own weapons.

But there is another and opposite class of theorists who regard education not as an agent for training the mind so much as a means of storing it with knowledge. The extreme partisans of this theory would teach the student nothing but what is of apparent and immediate use; above all things they would teach him the sciences, both in their principles and also in the various details of their application to the industrial arts of life.

The mind of the student who has undergone a training of this kind carried to its extreme, resembles the inmate of a house which is not so much well furnished as filled full of furniture. In the accumulation of mere material, anything like plan or principle has been forgotten. It ought to be remembered that the value of a fact lies not in its existence somewhere in the mental storehouse, but in the readiness with which the mind can find it when required.

Now between these two extreme theories it is surely possible to steer a middle course; it is possible to avoid grounding on Scylla without being swallowed up in the vortex of Charybdis. In the material world, what would be said to a man who insisted upon developing bodily strength by a course of gymnastics without reference to food, or of another who insisted upon doing the same by a course of diet without reference to exercise? But is the separation more natural in the mental world? Is not that mind most perfectly disciplined which is at the same time most perfectly informed? The student who has been disciplined by only one branch of knowledge is, I venture to think, the possessor of a mind only partially disciplined, as it is only partially informed. He may not easily perceive his deficient discipline, but in after-life he must often have cause to regret his deficient information. Nor is he whose mind is inordinately stored with scientific details one whit better off. Facts in education ought to be strictly subordinated to principles. A sound principle of science clearly understood will embrace a great multitude of facts, just as a simple rule of arithmetic will enable us to obtain a thousand products, each of which we should have to remember were it not for the rule. And in other branches of science, if the triumph of principle be not so apparent, it is only because we have a less accurate knowledge of its fundamental laws. It would be difficult indeed to say how many of the failures in the various walks of life are due to the neglect or ignorance of some principle which has either been omitted or dismissed from our calculations. From our leaders downwards we are a nation systematically ignoring principles, and in the minds of many a high esteem for fact is held to be quite consistent with a contempt for theory. A theory is not regarded as the very sap and life-blood of the tree of knowledge, but rather as the mildew that blights its leaves, or the worm that gnaws its root. Facts and theories are esteemed by this class of men to be sworn foes to each other, and the philosopher is supposed to live in a world of his own, rather hostile than otherwise to the world around him.

The existence of the two extreme educational theories to which I have alluded would thus seem to indicate the wisdom of a middle course. We ought to start from a platform as comprehensive as possible. Literature and science ought to go

hand in hand in producing the well-trained and well-informed disciple. And while there ought to be a broad basis of instruction common to all, there should be raised upon this common basis several distinct departments, so that the student may have the opportunity of attaining proficiency in that of his choice.

Professor Stewart next touched upon the subject of energy.

If an egg be allowed to rest on its shorter axis it will remain stationary, and any attempt to alter its position will be resisted by the egg. But the case will be different if we succeed, as perhaps we may, in causing it to stand on its longer axis, for in this position the slightest force will cause it to topple over. In the first case the egg is in stable, but in the second case it is in unstable equilibrium.

If it stand upon its longer axis at the very edge of a table, we cannot tell whether the first slight breath of air will cause it to fall inwards upon the table or outwards over the table, to be dashed to pieces on the floor. It is a case where a very slight cause may determine a very considerable issue as far as energy is concerned. Whether the egg will retain its energy of position by falling on the table, or whether it will convert this into the energy of motion, and ultimately into heat, by falling upon the floor, is an issue that depends upon a cause too minute to come within the scope of our calculations.

Now we have two types of machines, and in one of these we take advantage of the principle of stability, while in the other we use the principle of instability. A clock is a very good instance of a machine of the first kind. When a good clock has been wound up, we are perfectly sure that at noon to-morrow both its hands will stand at twelve, and that its weight will have fallen through a distance which we can calculate with the utmost exactness, if we take the trouble, all its movements being capable of the most rigorous calculation. On the other hand, a mine that is about to be fired by means of an electric battery is a machine or combination in which advantage is taken of nature's unstable arrangements. The powder which is about to explode represents chemical instability, just as the egg on its longer axis represents mechanical instability. The slightest percussion, the smallest spark, will rouse the imprisoned giant which it contains into volcanic energy. This spark has to be sent from a distance by the galvanic battery, and to do this we must complete the circuit. We cause the two wires to approach each other until they are only a very small fraction of an inch apart, but the contact is not yet complete—another touch, so slight as to be imperceptible, and the current passes, the powder is ignited, the mine explodes, and the fortress is hurled into the air. In such machines, great results, great transmission of energy, are due to the most trivial disposing causes. It depends at last upon the smallest conceivable movement of the wires conveying the current whether or not the fortress is to perish.

Nature also employs these two varieties of mechanism. In the solar system we have a clock on a large scale, only very much more accurate than any time-piece we can produce. The movements of every planet in the solar system are susceptible of the most rigorous calculation, and we have only to point our telescope properly in order to tell to the fraction of a second when a given planet will cross the field of view.

But in the living forms with which this world is so plentifully endowed, we have machines which, viewed in their relation to matter, belong to the second order we have described. The object here is not regularity, but rather freedom of action. The motion of an animal is not like that of a planet—the latter yields to calculation, but the former defies it. Now it is probably somewhere in the mysterious brain chamber that the delicate directive touch is given which determines our movements, just as the slightest possible touch to the wire in the battery chamber explodes the distant mine. That mysterious thing we call life is not a bully who swaggers out into the open universe, upsetting the laws of energy in all directions, but rather a consummate strategist, who, sitting in his chamber before his wires, directs the movements of a great army.

While we are thus led to confine the directive action of life to the very boundary of the universe of energy, it must not, however, be supposed that we have solved the problem as to the nature of life. We have only driven the difficulty into a bor-

der land of thick darkness, into which the light of knowledge has not yet been able to penetrate. If there be truth in these statements, and if we see in a living being a machine in which great results are produced by an exceedingly small primeval impulse, are we not led to expect that the unstable forms of nature will here be largely made use of? We must not, therefore, be surprised that the materials of our bodily frames are eminently liable to decay, or that the very intensity of our life is to be measured by the rate of change taking place in the tissues of our bodies, so that possibly those parts which have during life the noblest and most delicate offices to perform, are the very first to perish when life is extinct.

But this unstable matter, which is so wonderfully worked into our frames, is derived from the food we eat. This food does two things for us: it gives us energy in the first place, and in the second it furnishes our frames with a quantity of delicately organized tissue. But food is ultimately derived from the vegetable kingdom, and that kingdom derives it from the sun, so that we are led to regard our luminary as the ultimate material source not only of our energy, but also of our delicacy of construction.

To come now to our own luminary—very remarkable strides have lately been made in our knowledge of its physical constitution. It is difficult to say when and by whom the existence of sun spots was first remarked. Galileo, however, was the first to use them as the means of determining the elements of the sun's rotation. Besides these black spots on the sun's surface, equally mysterious forms have been seen to surround the sun on the various occasions of a total eclipse; these generally went by the name of red flames or red protuberances. Mr. Warren De La Rue was the first to prove that these phenomena were attached to the sun himself, and that the only office of the moon during an eclipse was to subdue the general light sufficiently to render them visible to the eye. While the red flames thus became objects of cosmical interest, Schwabe in Germany, and Carrington in this country, had both done much to increase our knowledge of sun spots. Schwabe, by a patient course of forty years' observations, had proved the existence of a well-marked periodical fluctuation in the amount and frequency of sun spots, the period of which was about eleven years. Carrington, again, had shown that the region of spots was a somewhat limited one, extending to about 20 or 30 deg. on either side of the solar equator, so that a spot never appears at the sun's pole, and he had also detected a proper motion of spots. Schwabe and Carrington had, however, confined themselves to mapping down accurately what they saw; but De La Rue, by the introduction of celestial photography, was enabled to obtain autographs of the sun which might be studied at leisure with an absolute certainty of their being correct. A large number of such pictures has been already obtained, and they are in the process of examination by Mr. De La Rue, and those associated with him in this research.

Some of the preliminary results of this examination have already been published, and they seem to point to a connection between the behavior and frequency of sun spots and the positions of the chief planets of the system.

Our acquaintance with the red flames has extended as rapidly as our knowledge of sun spots. It was discovered independently by Janssen and Lockyer, that these strange protuberances yield to the spectroscope under ordinary conditions of the sun, and without the necessity of waiting for a total eclipse. They exist in fact, always round the sun, but their brightness is quenched in the diffused light which surrounds the sun's border. When, however, we apply a sufficiently powerful spectroscope, the diffused light—consisting of ordinary sun light, and therefore containing a great variety of rays—is drawn out into a long spectral ribbon, and has its brightness scattered or diffused over the various parts of this ribbon, while on the other hand the light from the red flames, consisting only of one or two kinds, appears in the spectroscope as one or two bright lines not having their intensity weakened by the scattering action of the spectroscope. They, therefore, stand out in the field of view, while the ordinary light disappears. Lockyer has found, by this means, that there is an envelope of incandescent hydrogen surrounding the glowing surface of the sun, into which there are frequent injections of heated matter from beneath, and

in which there are violent hurricanes often moving at the rate of 100 miles a second. By the laboratory labors of Frankland and Lockyer, taken in connection with the solar observations of the latter, there is, I think, a probability of our ultimately ascertaining the pressure and the temperature as well as the chemical composition of the atmosphere of our luminary.

Descending now from the celestial bodies to our own earth, there is some reason to suppose that we are knit to our luminary, and possibly through him to the other members of our system by some other bond, besides that usually recognized. General Sir E. Sabine appears to have proved that disturbances of the earth's magnetism take place most frequently in those years in which there are most sun spots. This is confirmed by the experience of the present year, during which we have had a great number of sun spots, and frequent and large disturbances of the earth's magnetism.

I have already alluded to a possible connection between the behavior of sun spots and the positions of the planets; to which we may add that Schwabe and other observers imagine that they have discovered traces of a periodical variation in the appearance of the planet Jupiter. All the observations would appear to indicate the existence of some unknown bond between the different members of the solar system.

But that department of cosmical physics which is of most immediate interest to ourselves, is undoubtedly the meteorology of our globe; and here it is of great importance to know whether the earth's climate and atmosphere are influenced in any way by the changes taking place in the atmosphere of the sun. Such a connection has not yet been traced, but it has hardly yet been sought for in a proper manner. Recent observations discussed by Baxendell lead us to think there may be some connection between the daily changes in the earth's magnetism and the daily motions of the air. Coupling this with the fact that the frequency of terrestrial magnetic disturbances would appear to be connected with that of sun spots, we are led to contemplate at least the possibility of some connection between meteorology and sun spots.

If these remarks are of any value, they tend to indicate the probable union of the various branches of observational inquiry into one great cosmical research, and point to the wisdom of a very close union between the workers in the cognate fields of meteorology, terrestrial magnetism, and celestial physics.

At the present moment the prospects of meteorology are more hopeless than those of the other two branches. Our knowledge of the motions of the various components of the earth's atmosphere is extremely limited, and yet without this knowledge it is impossible to connect meteorology with the other branches of cosmical inquiry. If we endeavor to analyze the causes of this backward state of meteorological research, the first and most apparent is the magnitude of the problem. We are too intimately associated with the earth and its atmosphere to be easily able to tell its motions. Strange to say, the meteorology of the sun is more easily studied than that of the earth, and we know already as much about the strength of solar storms as we do about that of terrestrial hurricanes.

But another cause of the backward state of Physical Meteorology arises from the fact that there are two branches of science, each of which may be furthered by meteorological observations. There is first the physiological branch of meteorology, the object of which is to trace the influence of climate upon animal and vegetable life; and there is next the physical branch, the object of which is to study the physics of the earth's surface, and more especially the motions of its atmosphere.

It is now high time that a separation should be made in the mind of the observer between these two branches of research. If he would rather pursue the physiological inquiry, let him say so definitely, but if he wish to pursue physical meteorology, let him clearly keep before his mind the object of all his labors. He should ask himself the question, what is the best system of observation, and what is the best method of reduction, to advance the great object of physical meteorology—a knowledge of the motions of the earth's atmosphere, and of the causes thereof? He should not fix upon a system of observations and a method of reduction that may possibly, but upon one that must necessarily, further this great object.

I have thus endeavored in a few words to bring before you the recent advances in cosmical physics. Besides this, there are two other no less important branches of physical inquiry. We have the physics of organized beings, and we have also molecular physics. But there is this difference between these two branches and that of which I have now spoken:—To forward physiology or molecular physics we chiefly require experiment, but to forward cosmical physics we chiefly require observation. You are all aware that at the present moment a Royal Commission is inquiring as to the relation between Science and the State; and perhaps, therefore, you will permit me the opportunity of stating my views as to the manner in which this very necessary assistance may best be given. I think that those branches of science which demand for their extension experiments not requiring very great time, may be furthered with much advantage in institutions such as Owens College. I believe it to be advantageous to bring the highest class of physical teaching into contact with research. If Government be disposed to grant pecuniary aid to such researches, an extension of the allowance made annually to the Government Grant Committee of the Royal Society would appear to be a very legitimate way of accomplishing this object.

The scientific professors of a college would thus have to state the aim of their research to a committee of the Royal Society intrusted with the disposal of Government means, and the requisite funds would be forthcoming. No one, I think, can doubt that the small sum of £1,000 annually intrusted by Government to the Royal Society for miscellaneous experiments, is administered in a most praiseworthy manner; and if Government would be ready to grant, and the Royal Society willing to undertake, an extension of this trust, it would, I think, be a great point gained for this class of physical experiments. (I speak only of experiments, but the encouragement of experimenters is a point of equal importance.) But when we come to experiments and observations requiring great time, the case is very different. Certain experiments, whether from the great time they require, or the great expense they demand, cannot be well performed in a college; while routine and long-continued observations such as those connected with the various branches of cosmical physics, are of such a nature as to require a central establishment to superintend their organization and reduction. There is thus, I think, the necessity for a central establishment of some kind devoted to that class of experiments and observations requiring great time, great space, and great expense for their completion.

Referring more particularly to Cosmical Physics, I feel convinced that meteorology should be pursued in connection with terrestrial magnetism and solar observations; and were a well-considered scheme for solving this great problem fairly introduced, I am sure that scientific institutions and individuals throughout the country would do all that they possibly could to promote this most important branch of physical research.

THE CAUSES OF RAILWAY AXLE FRACTURE, AND THE REMEDY.

BY W. BRIDGES ADAMS.

From "The Journal of the Society of Arts."

The fatal accident which has slain so many persons, and maimed so many more, perhaps for life, and the impossibility of ascribing blame for its occurrence to any individual or corporate body, leads us to the inquiry as to the possibility of future precaution. The contingency of one train damaging another at the moment of passing each other on two lines of rails seems at first a remote one, but of course the chances in favor of it will be on the increase with the increase of traffic, and it is therefore worth analysis.

That the breakage of the axle was caused by a gradual deterioration of material, may be assumed *a priori*, for the wagon, so far as we know, was one long in use, originally constructed to carry 6 tons, and loaded with less than that amount when the axle suddenly broke.

WHEELS AND AXLES.

In discussing the question of wheels and axles, we must first define them, for there are wheels proper, and wheels so-called, which are not wheels at all, but only rollers. In its principle, what is called in railway parlance an axle and pair of wheels is, in truth, only a garden roller with the centre portion cut away. If any one tries to pull a garden roller round in a small circle, he will soon find himself in the difficulty that it is a sledge, and not a rolling body, that he is working at. The garden roller is a revolving axle, with the wheel fixed fast on it, and so is the railway axle. Some long time back, an agricultural machine maker patented and made what he called a clod crusher. It was a revolving harrow, some 7 ft. in length, set all over with spikes. But no power of horses could draw it, save in a straight line. To change its course was impracticable, because both ends would persist in travelling at the same rate of speed, a practice strictly in conformity with geometry. So our would-be clod-compeller was compelled by the clods to change his practice. He divided his roller into two separate wheels, each being enabled to revolve separately on the axle. Still, each wheel was so broad that he gained little advantage. He then subdivided it into four wheels, and it was much more easily managed, and he carried on the subdivision till he had reduced his rollers to the width of ordinary wheels, all strung on one axle together. In fact, he had gone through once more all the original contrivances which had in past ages developed wheels out of a roller, and this is precisely the process to which railway mechanicans must, sooner or later, address themselves. They must take to wheels proper, and eschew garden rollers, however cunningly they may cut and carve them into fanciful forms, conical or other, for it is a law of nature that, to avoid friction, wheels must travel at differing rates of speed along pathways of differing lengths.

It is recorded that when Donald Macdonald first descended from the Highlands and beheld a four-wheel carriage travelling along with a Lowland Earl, he first stared with astonishment, and then burst into a fit of laughter, exclaiming, "Weel rinnit, wee wheel, big ane canna catch ye," not realizing the fact that the big wheel made fewer revolutions.

It is quite true that by making, in railway practice, each half of the garden-roller the frustrum of a cone, it is possible so to vary the diameters as to be the equivalent to separate wheels, provided sufficient end-long movement of the axle be arranged. But this only holds good as regards a single axle, and vehicles with a single axle are not prevalent on railways; they have never less than two, and sometimes more. The frames to which these axles are attached are oblong, and the axles are supposed to be rectangular to the frame, and parallel with each other, the line of traction being parallel with the planes of the so-called wheels. So arranged, they are adapted to run truly on straight lines of rails. But such straight lines are purely imaginary. Rails are a succession of large and small curves and zigzags, on which the coned rollers incessantly vary their tread, and oscillate from side to side, on sinuous courses, like so many snakes, but not so gracefully. In this oscillating movement the rollers are seeking the path of least friction; and so well is this understood by the engine-drivers that the trains of wagons are coupled only by loose chains or links, for the simple reason that, were they close-coupled together, the friction of the treads and flanges against the rails would be so great that it would be impossible to haul them along. With passenger trains this sinuous motion is so annoying that, perforce, the train is coupled close together to check it, and the wheels or rollers tell the story of the additional friction they thus have to encounter, by the amount of frictional vibration and retardation thence ensuing. And frequently at stations the driver will take the opportunity to loosen the couplings, in order to ease his engine.

LONGITUDINAL SHOCKS.

Longitudinal shocks of more or less intensity, occur in all trains, whether in drawing or propelling, and if the traction and buffing springs be insufficient in elastic power, the frames, especially on curves, are apt to get a diagonal set. In wagons without traction springs or buffing springs, the haulage, by loose couplings, is a succession of violent jerks, frequently breaking the couplings and causing accidents.

And again, when the buffers on one side get violent blows on curves, the oblong frame becomes rhomboidal, and though the axles retain their parallelism with each other, they cease to be rectangular to the line of traction, and the wheels remain at a permanent tangent with the rails. In this position the strain upon the axle, by the pressure of the wheel flanges against the rails, becomes enormous, and the longer the wheel base the more mischievous it is.

HAULAGE RESISTANCE.

It may be taken as an axiom that resistance to haulage—apart from gravitation on inclines—is the measure of axle strain in torsion. The normal resistance is assumed to be 8 lbs. per ton of load on the axles, on the level. If, then, we find, as sometimes occurs, that trains of wagons will not run down inclines of 1 in 72 without haulage, we may be sure that there is something vicious in the structure, whether original or induced by violence. Curves and bad permanent way will quadruple the resistance to traction, and practically the resistance in being obliged to shunt a train into a sharp-curved siding will reduce the train by one-third to one-half of what the engine is able to deal with on a straight line.

AXLE TORSION.

Under these circumstances, the railway axle is exposed to great torsional strain, with a condition more trying than that of the fixed axles on the common road. The common road axle being a fixture, if it be weak for its load, any bending is only in one direction, viz., upwards at the ends. If the revolving axle bends under the load, it bends in every direction radial to the centre in a constant succession of changes. The bending, of course takes place in the weakest part, where it is reduced for the bearing, or for the boss of the wheel. If it bends at all under the load, aggravated by eccentricity of movement, the final breakage is only a question of time. The commencement is by a fine circular line round the weak part, so fine as to be undiscernible by the naked eye. This line gradually deepens to a sixteenth of an inch, half an inch, and so on till the central portion becomes too weak to hold it together and it drops apart. Breakage of axles in this mode is not uncommon, and those who have locomotive engines in charge, with cranked axles, maintain that the access of oil in the opening crack acts as a wedge to quicken the fracture, and the question of duration is a known quantity. In truth, the crank axle of an engine is a very weak axle. Its diameter is usually the same as that of straight axles, while its length, if straightened out in the cranks, will be found to be double that of the straight axle.

BREAKING STRAIN.

It will be seen, then, that the cause of the breakage of railway axles is to be found in the fact that they are strained beyond their powers, not by the load, but by imperfect structure of the vehicle they are attached to—imperfect, possibly, originally, but commonly by violence in use. The running is "wringing the neck of the axle."

With a view to lessen lateral friction of the wheel flanges as much as possible, it has been customary to keep the axles as near as possible together. This, if the bodies be long, involves "hogging," and oscillation, with a bad distribution of the load. Other things being equal, the nearer the axles are to the wagon end, the steadier they will be; but then flange friction increases with the length of wheel base, and a remedy must be provided for this.

Supposing that a train of wagons were built perfectly true at the outset, for a straight line, the multitude of longitudinal shocks would soon set the wheels out of truth, and so the question arises, whether it be possible so to construct them that diagonal shocks to the frame, giving a permanent set, shall not affect the true running of the wheels; and next, whether wagons may not be so constructed as to dispense with the loose coupling, which is a material source of breakage to couplings, and displacement of the wagon frames. We think it is. Desirable as it is to point out the causes of the defects, it is still more useful to point out the remedy.

EXISTING STRUCTURE OF VEHICLES.

The existing mode of construction is, to fix to the sides or sole bars of the wagon four iron forks called horn-plates, up and down which the axle boxes slide vertically with the movement of the bearing springs, similar to the row-locks of a boat which

hold the oars. The fit of these horn-plates in the grooves of the boxes must, of course, be a loose one, or they could not work equally. Consequently, every blow which disturbs the frame carries the horn plates with it, and sets the wheels and axles askew.

IMPROVED STRUCTURE.

The horn-plates are dispensed with, and, instead of them, axle-guards are made to clip the two axle-boxes firmly, and bend round the wheels horizontally, and form a central pivot-hole 7 in. within each axle. A strong pivot is forged on a plate turning up at the ends, and bolted between the two diagonal timbers of the wagon frame at each end. The axle-guard frame thus forms a caster-pivot, which carries no load, but merely acts as a guide or eccentric centre for the wheels. The bearing-springs are fixed on the axle-boxes above the axle-guards, and carry the load by long pendant round rods, with ball and socket heads and nuts passing through strong iron brackets fixed to the sole bars. Thus there is perfect free movement for the axles to move laterally and radially on irregular rails, or when the wheel-flanges press against the outer rails on a curve—when the axles take a true radial position pointing to the centre of the curve, each independently of the other. If any distortion happens to the frame by a blow, making it rhomboidal, it does not affect the relative position of the two pivots, and the wheels will run as true with a distorted rhomboidal frame as with a true oblong; and on a straight line the gravitation of the spring shackles insures a rectangular position.

And this free movement of the wheels from side to side, while preventing all jamming of the flanges, will permit the close coupling of the trains without affecting the wheel action, and thus reduce the longitudinal shocks to the minimum. Thus the wagon bodies may form a series of tangents on a curve, free from oscillation. The buffers are curvilinear to give free action. It will be seen that the short distance between the axle centre and the axle-guard centre, while keeping the wheels true on curves, also keeps the wheels true to the gauge, and free from oscillation. The wagon is adapted to carry 10 tons of coals or minerals quite steadily at any speed. The spring-plates are 6 in. broad, and thoroughly elastic. The cubic contents are 381 ft., and sliding iron bars are made to clip the upper edges, permitting loading without trouble, and holding the light top sides together.

COAL WAGONS DIRECT FROM THE PIT'S MOUTH TO THE CONSUMERS' PREMISES WITHOUT CHANGE.

On this system, the cones of the wheels or rollers may be brought into effectual play, widening the gauge of the rails where the curves are very sharp, thus enabling coal wagons of 12 ft. wheel base and 20 ft. length to go direct to the pit's mouth round curves of one cha n radius. Such wagons also will permit the delivery of coal direct from the pit's mouth on to the consumers' premises, such as large gas-works, running on the wheel flanges, on channel rails laid on the streets and roads as tramways, as shown on the diagram. It is true that very sharp curves would involve tread friction, as may be any day seen in street-tramway working, but this can be very easily provided for, and then the movement becomes perfect, and the friction on the channel rails would be less than that on the railway proper, as the flanges would cease to rub.

It is thus possible to get rid of the contingency of railway axles breaking by unfair wear, when otherwise faultless. And when we get to the proper process of forming hollow axles, we shall have far less chance of flaws. And if coal and goods wagons be thus constructed, they may run at as great speed, and with more safety, than existing passenger trains. The cost and consumption of fuel is mainly governed by the resistance to haulage.

EVIDENCE ON INQUEST

The intelligent evidence given by Mr. Sacré and Captain Tyler made the matter very clear:—"The wagon was estimated to carry a load of 6 tons, and the dead-weight of the wagon, unloaded, was 2 tons 5 cwt, and it had been in use 18 years." This was a satisfactory and economical proportion, of ample weight for strength, without the surplus dead-weight we have heard so much of lately. Captain Tyler said, "the flaw was round the whole circumference of the axle-tree.

The flaw was not due to the quality of the iron, but arose from wear and tear. A large portion of the section of the axle had been defective, and it was only a moderate-sized piece in the middle that held on. As the truck worked, the sound portion got smaller, and at last it got so small that it failed altogether."

This is precisely the process of breakage in all railway axles subjected to a bending strain, either by overloading, or by torsion on sharp curves, or by vicious or damaged structure.

In the running of ordinary trains, the tendency is for the leading wheels to hug t e outer rail with their flanges where the lines are curved, and the result of this is to throw the trailing-wheels against the inner rail, placing the vehicle in a partly diagonal position, with an incessant sledging, frictional grind, inducing the "wear and tear" to which Captain Tyler alludes. If the wheels were free, instead of being held fast laterally to the frame, they would find out for themselves the path of least friction; the torsion of the axles would cease, and oscillation of the bodies would disappear also. And be it remembered that the tendency to hug the rail with the wheel flange with rigid pressure is the main cause of "getting off the line."

Mr. Patrick Stirling, the engineer of the Great Northern Railway, and than whom no more competent engineer exists, said: "It is quite possible the flaw in the broken axle might have been an incipient one at the time of its original construction, but not perceptible to the eye. A concussion with another wagon might have completed the break of the axle in question. There is a considerable curve in the locality of the accident. A curve always brings a greater strain on the axle than a straight line."

CRANKED AXLES.

In February, 1869, a paper was read on the Mauritius Railway, at the Institution of Civil Engineers, and, in the course of the discussion on locomotive engines, Mr. Harrison, the Engineer of the North-Eastern Company, made the following remarks: "Mr. Adams had stated that he could make an engine which would pass round curves of three chains radius. He knew that gentleman's radial motion had been successfully applied to engines and carriages, and he had no doubt that Mr. Adams was going in the right direction in designing stock for traversing sharp curves, but still he thought it would be much better, if possible, to avoid sharp curves, and thus remove the necessity for adopting these means of working. It was only when the curves were exceedingly sharp that it was necessary to resort to these expedients. There was no stronger argument against very sharp curves than the comparative wear of crank axles on curves and on straight lines, and he could state from experience that a crank axle in an engine working on straight lines would last at least six times longer than the crank axle of an engine working over exceedingly sharp curves."

Jeremy Bentham was accustomed to remark that "it would be a great mechanical convenience if the surface of the world were all down-hill; but that as it was not so, he must put up with it." And even so we must deal with our railways. Let us by all means get straight lines when we can; and it would be better, on the whole, to make straight lines in given lengths, connected by sharp curves at intervals, than to form them in general curves; only, in such case, we must take care that our moving stock be adapted to work the curves; and, in any case, our wheels and axles should be so constructed as to have free rolling movement under all circumstances, and never be subjected to other strains than that of the direct load borne upon them. With regard to crank axles, there is no apparent reason why they should exist at all, other than a superstition. Straightened out in the cranks, they measure twice the length between the wheels that straight axles do, and yet, strange to say, they have no increase in diameter. The steadiest, fastest, and most powerful locomotive engine now existing on any English line has been produced by Mr. Stirling, and it has a straight driving axle and outside cylinders. It could scarcely exist at all for any useful purpose with a crank axle; and, with requisite appliances, it could, no doubt, work with coupled drivers and increased power.

SUMMARY.

The faults and accidents are not in individuals but in the system of all large establishments, whether government or other, that sticks to red tape and eschews

progress, that would build every locomotive and wagon to an antique pattern, in order to save trouble in organization, as though the works of man were as perfect in their beginning as the works of the Creator; as though there were not construction, destruction, and reconstruction in nature itself. But for the competition of individuals, we should still be travelling in stage-coaches drawn by horses, and building wooden war-ships, till the world were denuded of its forests. Not for this were our iron and coal stored in the underground cellars of nature!

RESISTANCE TO TRACTION.

Translated from "Weisbach's Mechanik der Zwischen" und "Arbeitsmaschinen."

According to numerous experiments made by Morin, the resistance of a good concrete or macadamized road to the motion of a wagon is—

(1.) Nearly in direct proportion to the load.

(2.) Inversely proportional to the height of the wheel.

(3.) Nearly independent of the number of wheels and of the breadth of tire.

On soft or yielding roadway, or upon a road just macadamized, the resistance diminishes with the breadth of the wheel. For slow motion, the resistance is independent, or nearly so, of the velocity; and it is as great for wagons with springs as for those without. If the motion is rapid the resistance increases, being nearly proportional to the velocity; it is less if the wagon has springs. The traction in this case diminishes with both elasticity of road and elasticity of vehicle.

MEAN DIAMETER.	Freight Wagons.		Carts.		Coaches.	
	4	4½	5	6⅔	3⅓	3⅓
					Walk.	Trot.
I. BROKEN STONE.						
1. In good condition, dry and smooth	1/80	1/85	1/88	1/93	1/48	1/41
2. Somewhat damp, dusty, and with scattering stones.	1/58	1/61	1/67	1/69	1/34	1/27
3. Very hard, coarse stones, wet	1/43	1/50	1/57	1/71	1/25	1/27
4. Hard, shallow tracks in soft surface coat	1/27	1/32	1/36	1/46	1/26	1/23
5. Hard, tracks	1/25	1/26	1/30	1/37	1/21	1/18
6. Much travelled, thick coat of mud	1/19	1/22	1/25	1/31	1/18	1/16
7. Cut up, tracks 2 to 3 in. deep	1/14	1/17	1/19	1/24	1/14	1/12
8. Very bad, thick coat, bottom hard, tracks 3 to 4 in. deep	1/13	1/16	1/17	1/21	1/12	1/10
II. CONCRETE.						
1. Very good	1/65	1/73	1/76	1/103	1/63	1/43
2. Ordinary, dry	1/50	1/56	1/59	1/100	1/37	1/31
3. Ordinary, wet and coated	1/46	1/54	1/74	1/76	1/44	1/33
III. WOODEN ROADWAY OF A BRIDGE.	1/43	1/50	1/69	1/71	1/41	1/41
IV. DIRT ROAD.						
1. Very good and dry	1/27	1/32	1/36	1/46	1/26	1/26
2. Gravelled 1 to 1½ in. deep	1/20	1/24	1/24	1/27	1/19	1/19
3. Gravelled 2 to 3½ in. deep	1/9	1/10	1/12	1/15	1/9	1/9
4. Gravelled 4 to 5½ in. deep	1/8	1/10	1/11	1/14	1/8	1/8
V. UNBROKEN SNOW.	1/14	1/17	1/19	1/24	1/14	1/14

A breadth of tire of 4 @ 4½ in. is most advantageous, as narrower wheels cut the road, and power is not economized by the use of wider.

Theory shows the traction to be proportional to $\left(\frac{L^4}{b\,r^2}\right)^{\frac{1}{3}}$; *i. e.*, it is directly as the cube root of the 4th power of the load, and inversely as the product of the breadth and the square of the radius. This does

not correspond with the empirical results mentioned above. We have $(L^4)^{\frac{1}{4}} = L(L)^{\frac{1}{4}}$; $(r^2)^{\frac{1}{4}} = \left(\frac{1}{r}\right)^{\frac{1}{4}}$. r and $(1.1)^{\frac{1}{4}} = 1.032$.

Hence if the values of L, r, and b vary within narrow limits, differing from a mean value by not more than 10 per cent. we may, instead of 1.032, substitute 1, and instead of $(L)^{\frac{1}{4}}$, $(\,)^{\frac{1}{4}}$ and $(b)^{\frac{1}{4}}$ make use of constant mean values. We should then have, with Morin, the traction directly proportional to the load, and inversely to the radius, and independent of the breadth of tire. This receives further confirmation from the fact that resistance is also proportional to the friction of the axles as well as to concussions; and that when these conditions are introduced into the theoretical problem the resulting proportions agree with those deduced from experiments.

The preceding Table contains co-efficients of resistance under the conditions specified. In order to find the force, P, necessary to draw the load L, the total weight of load and wagon must be found, and this sum must be multiplied by the coefficient. If the road rises, the result must be increased by the product of the result thus obtained by the sine of the angle of elevation.

FRICTION.

From "The Iron Age."

When a body is pressed upon the surface of another, it is moved along that surface with difficulty. If you attempt to cause one of the surfaces to slide on the other, a certain force opposes itself to the effort, which is found to become greater as they are pressed together with greater force. By rendering the surfaces of contact more smooth, or by interposing unguents between them, the amount of this resistance, called friction, may be greatly diminished, but it never can be altogether dispensed with. The principal experiments which have been made upon friction have reference: First, to the proportion in which the friction increases with the pressure of the same surface. Secondly, to the variation of the amount of friction produced by the same pressure upon equal surfaces of different substances. Thirdly, to its relation to the size of the surface of contact, the pressure being the same; to the influence of the time during which the bodies have been in contact on the amount of the friction; and, especially, to the distraction between the friction which resists the first motion of a body from rest, and that which opposes itself to its motion during the continuance of that motion; and we quote from the best experiments on the subject made by Coulombe, Prof. Vince, Mr. Rennie, and M. A. Morin. It has been clearly demonstrated by these scientific gentlemen, that the friction is always proportionate to the pressure; for if the surface of one body be pressed upon that of another with a certain force, and if that be doubled, the friction will be doubled; if the force be increased three times, the friction will be tripled, and so on; and from the tables here attached, the following may be mentioned as general conclusions :—

First.—That the ratio of the friction to the pressure in all hard metals, for pressures less than 32 lbs. on the square inch, is nearly the same, and for these metals the friction varies one-sixth the pressure. *Second.*—That the friction of soft metals is very much greater than that of hard ones. *Third.*—That the same relation exists in respect to the frictions of soft and hard wood: two surfaces of pine being pressed together, exhibited a friction equal to more than one-third pressure, while the friction of the surfaces of teak or oak was scarcely more than one-ninth pressure. Whether the fibres of the two surfaces of wood be parallel or perpendicular materially affects the amount of friction, and whether they be wet or dry. Of oak on oak, fibres being parallel, the ratio of friction to the pressure was from 60 to 65; when the fibres were perpendicular, the ratio was 51; when the surfaces were wetted, it rose to 71. It is a practical fact, that friction is considerably augmented in the surfaces of wood by wetting them.

Friction is less between surfaces of dif-

ferent kinds than between those of the same kind, and two metals of the same hardness should never move on one another, though Leslie asserts steel to be an exception; but recent experiments prove that fine brass moving on a steel journal has considerably less friction than steel on steel, and consuming less oil *pro rata* of load. Friction is greater at the first moving of the load than when fairly in motion, and it is asserted, in regard to different degrees of velocity over a certain space, that, as a general rule, the friction is the same for all velocities.

The amount of friction is independent of the extent of the surface pressed, provided the whole amount of the pressure remains the same, and that the extent of the surface pressed is the same. By increasing the surface which supports the pressure, you diminish the amount of pressure upon every point of it, and thus you diminish the friction on every point; although there are more points which rub, their aggregate amount of friction is only the same as before.

The friction of a body, when in a state of continuous motion, bears a constant ratio to the pressure upon it, which is the same whatever may be the velocity of the motion. This fact was clearly proved by M. Morin, by extensive experiments under order of the French Government.

The general effect of unguents upon friction is materially to diminish it; but it is important to state, however, that they entirely destroy the constant ratio which, without unguents, friction is found to bear to the pressure. Thus, Mr. Rennie found that the friction of an axle of yellow brass upon a collar of cast iron was, without lubrication, in every case $\frac{1}{4}$ the pressure; when the surfaces were oiled this ratio became, under a pressure of $\frac{1}{2}$ cwt., only $\frac{1}{37}$, but when increased to 11 cwt. it rose to $\frac{1}{8}$. Axles of brass, made of copper and tin, moving in cast-iron journals, exhibit, when lubricated, the least amount of friction, and the best lubricator appears to be clean tallow. With this unguent the mean results of Rennie's experiment show, for a pressure of 1 to 5 cwt., a friction of $\frac{1}{39}$ the pressure. It is still a more remarkable fact that the softer lubricators, as whale oils, hog's lard, sweet oil, etc., increase the ratio of the friction to the pressure, while harder lubricators, as soft soap, tallow, and carefully made anti-friction metals, greatly diminish it. The latter compound should be made of sufficient hardness to attain a high polish in the journal box from running on the journal; it should not be porous, but close-grained and fine in its crystallization, and not melt under a temperature of 700 to 900 deg., at which heat it should run free and clean into the mould or bearing; when cut with a chisel, by a blow from a hammer, it is tough, yet flying before the cutting edge of the tool; it will not fill the teeth of a file when brought in contact with it, but fall away in finely separated particles. We recommend its use in all machinery, particularly where high speed is obtained, or where the journals are likely to heat. It has been of the greatest advantage over a solid iron or brass bearing, from the fact that it will run with less friction, without oil; and even when heated so as to melt, it will do no injury or cutting to its running journal.

In the manufacture of these metals for anti-friction purposes, the author of this article has, by numerous experiments, tried to achieve the desired end, and is now offering to the mechanical community metals equalled by none for their anti-friction qualities. To produce metals that shall give the least friction to the greatest pressures, at certain required speeds, with or without lubricating compounds, and also making them wear, with ordinary care and mechanical management, equal to the best metals known in every respect. We regret to see some of our mechanics still insist upon using the lower and cheaper grades of Babbitt or anti-friction metal in their journal bearings. From long experience in machinery, we can distinctly assert there is no economy in its use, but sooner or later a constant source of annoyance to the purchasers of the machinery, and often the cause of their losing much time and trade in business. We, therefore, recommend all builders of engines and general machinists to buy a good article; resting assured that a good and reliable-wearing anti-friction metal cannot be made and sold at the low figures now offered in the market. A composition known to consist of a few parts of antimony to a large proportion of lead, with, perhaps, a trace of copper, cannot be called an anti-friction metal; but, from its soft, fibrous qualities, is just the reverse, and creates the very agent we, in a meas-

ure, wish to destroy. Many years' experience as an engineer, and a worker among machinery of various kinds, enables us to assert that too little attention is paid to those parts of moving machinery requiring special lightness and care in their construction, that the friction may be diminished; and probably no parts are more neglected than the journals, which, instead of having as much surface as possible, are often reduced to absurd dimensions, causing trouble in the machinery, annoyance to the engineer, and an ill-reputation to the engine-builders and to the material of which journal boxes are made of or packed with. Instead of anxiously caring for these important moving parts, giving them the best materials in construction, and the best lubricators, they are too often supplied with inferior workmanship and metals, and the result is an early destruction of the machine. And often at such times it is no uncommon practice among persons having charge of heavy or fast moving machines to keep a constant stream of cold water running upon the

Surfaces of Contact.	Friction of Motion. Coefficient of Friction	Friction of Quiescence. Coefficient of Friction.	Unguents.
Oak on oak, fibres parallel	0.075	0.164	Tallow.
Oak on oak, fibres parallel	0.067	0 067	Hog's lard.
Oak on oak, fibres perpendicular	0.083	0.254	Tallow.
Oak on oak, fibres perpendicular	0.072	0 254	Hog's lard.
Oak on oak, fibres perpendicular	0.250	0.254	Water.
Oak on cast iron, fibres parallel	0 080	....	Tallow.
Oak on wt. iron, fibres parallel	0.098	....	Tallow.
Wt. iron on oak, fibres parallel	0 256	0.649	Greased and saturated.
Wt. iron on cast iron	0.103	....	Tallow.
Wt. iron on cast iron	0.076	....	Lard.
Wt. iron on cast iron	0.070	0.100	Olive oil.
Wt. iron on wt. iron	0.082	....	Tallow.
Wt. iron on wt. iron	0.081	....	Lard.
Wt. iron on wt. iron	0.070	0.115	Olive oil.
Wt. iron on brass	0 063	....	Tallow.
Wt. iron on brass	0.075	....	Lard.
Wt. iron on brass	0.078	....	Olive oil.
Cast iron on oak	0.189	....	Dry soap.
Cast iron on wt. iron	0.093	0.100	Tallow.
Cast iron on cast iron	0.314	....	Water.
Cast iron on cast iron	0.100	0.100	Tallow.
Cast iron on cast iron	0.070	0.100	Lard.
Cast iron on cast iron	0.064	——	Olive Oil.
Cast iron on brass	0.060	0.106	"
Brass on cast iron	0.077	....	"
Brass on wt. iron	0 061	....	Tallow.
Brass on wt. iron	0 072	....	Olive oil.
Brass on brass	0.068	0.108	"
Steel on cast iron	0.079	....	"
Steel on wt. iron	0.076	....	"
Steel on brass	0.053	....	"
Steel on brass	0.067	....	Oil and plumbago.

FRICTIONS OF AXLES IN MOTION.

	Lubricator properly supplied.	Lubricator continually flowing.
Brass on brass	0 079	.....
Brass on cast iron	0.072	0.049
Brass on wt. iron	0.073	.....
Wt. iron on brass	0 075	0.054
Wt. iron on cast iron	0 075	0 054
Cast iron on cast iron	0.079	0 054
Cast iron on brass	0.075	0.054
Cast iron on hard woods	0.100	0.092

journals. W cannot condemn this in too strong language, and have yet to see the benefit accruing from it; nor do we see, in our experience, any benefit from the immoderate use of flour of sulphur, black lead, etc., to reduce the friction or the heat of the heated journals. Our experience has taught us differently; we would reduce the pressure of weight upon the journals, slow the speed of the machine, use plenty of tallow and no water; and our word for it, the friction will be lessened in the shortest space of time, and our journals kept bright and smooth. We give above, tables of various experiments of M. Morin, under the special patronage of the French Government; he divided them under the heads: I.—Experiments on friction without unguents. II.—Experiments on friction of unctuous surfaces; that is, where some lubricator had been used, and then the surface carefully wiped, so that no perceptible unguent interposed. III.—Experiments with unguents interposed. Of these three classes of experiments, as no machine is placed in operation without lubrication, we will content ourselves by giving some of the data of the principal bodies upon their surfaces of contact and lubricators used.

The effect lost by friction in axle and bearing is expressed simply by the formula:

$$\frac{P = \pi d W n}{12.60} \quad \frac{f = W d n f}{230}$$

in which W=weight in pressure in the bearing; d=diameter on which the friction acts in inches; n=number of revolutions per minute; f=coefficient of friction in table. In ordinary machinery the coefficient may be assumed at 0.065, then

$$P = \frac{W d n}{3530} \text{ and horse-power} = H = \frac{W d n}{194150}$$

In conclusion, we quote from standard authorities these few simple facts: Coulombe states that friction of a sliding body equals 25 per cent. of the pressure, a revolving body 15 per cent., a rolling body 5 per cent. While Mr. Southern, in 65th volume "Philosophical Report," states that experiments made by him with a revolving body was 1-40th the weight, Mr. Wood found the friction of locomotive axles about 1-60th the weight, with ample lubrication with tallow, and greater with oils. Mr. George Rennie states that the friction of shafts, with a pressure of 1 to 5 cwt., is not more than 1-39th the pressure, with tallow lubricator and anti-friction metals interposed. Mr. Bourne, in his late treatise on the Steam Engine, writes and asserts, that where a composition metal is made of copper, tin, and antimony, a finer and more durable metal is presented for anti-friction purposes, and that the friction of surfaces was less in all revolving or sliding bodies; and, further, that the oils or unguents remained upon the surface longer, and the journals were less liable to heat. He too asserts that where the greatest pressure was, the hardest unguents were the best lubricators, and when the weight was lightest, oils, etc., were the best agents. With oils the friction appears to be the least when the pressure on the surface of a bearing is about 90 lbs. per sq. in.; but in every case, he adds, where the reduction of friction was an absolute necessity, the use of excellent anti-friction metals was a decided gain in power, a saving in machinery, and an economy of time, labor, and money.

A Railway "Traveller, Constructor, and Director," writes in the "Times:"—"Progress is rapid in these days, and railways have not attained perfection. New propelling powers will be discovered by the advancement of science, and I shall probably be set down as a wild enthusiast if I venture to prognosticate that in another generation our passenger carriages, instead of having their load placed above the centre of gravity, will be suspended below that centre by the elevation of the rails, by which accelerated speed will be obtained with greater safety than on the present system. But neither directors nor travellers are yet prepared for that sweeping but certain change. They are, however, I believe, prepared that we shall have a line for human beings, and another for luggage, upon our leading, and, I will add, generally well-conducted and well-managed lines. For the thought is not pleasant, that we may be burnt, as at Abergele, or precipitated down an embankment, as at Tamworth, by the blundering negligence of a careless pointsman."

The address of A. W. Humphreys, Esq., presented in this number, was carefully revised by the author for our pages.

SMALL IRON-CLAD SHIPS.

From "The Mechanics' Magazine."

At the late meeting of the British Association at Liverpool a paper was read by Mr. Michael Scott, C. E., N. A., upon a method of constructing ships-of-war of moderate dimensions. It is a relief to turn for a few moments from the sea-going turret ship controversy, and all the bitterness and obstinacy attaching thereto, to the consideration of something really practical and sensible in the way of iron plates, turrets, and big guns. Valuable suggestions or inventions are not always brought into the light of day with a flourish of trumpets, or under the patronage of the great and influential. There is such a thing as modest genius still in the world. If we are not greatly mistaken, the mechanical inventions which have from time to time been produced have generally made their appearance and made their way unaided by what is called the honor and intelligence of the country.

It would be easy for us to run back 50 or 60 years and prove the truth of this assertion, but it is unnecessary; the fact is too patent to require arguments or illustrations in proof thereof. The same principle which holds in philosophy, in morality, and in religion, holds in mechanics, viz., if a thing be true it will, sooner or later, make its way and be recognized. We have no hesitation in stating that we think highly of Mr. Scott's proposed arrangements for the building of war ships of moderate dimensions. In fact, there has been nothing so practical and efficient proposed since the building of the "Enterprise" and "Research." Since these two ships were built there has been no attempt on the part of our authorities to build small iron-clad ships. The Messrs. Laird built two small vessels—the "Wivern" and the "Scorpion"—which have proved utterly useless for the purpose for which they were intended. We believe that the true policy for the Admiralty to pursue now, is to build some small iron-clad ships to act in concert with the huge and heavy ships which constitute our fleet. We think that Mr. Scott's ship will fulfil the required conditions. At any rate, nothing better has yet been proposed, and we therefore advocate the adoption of his design. Mr. Scott's plan for a small ship-of-war is intended to compete with a "breastwork" monitor, as designed by Mr. E. J. Reed, C. B., late Chief Constructor of the Navy. The main object of Mr. Scott's plan is to reduce the amount of armor to the smallest possible extent, and so to dispose that which he must of necessity have, as to protect the vital parts of the ship. Mr. Scott believes in a high freeboard as being essential for rendering a ship seaworthy, and he also believes that a high freeboard is not incompatible with the turret system. To quote Mr. Scott's words, he has "designed a structure, to wreck even the non-vital parts of which would occupy the most powerful modern war ships so long a time that before their task could be accomplished they themselves might be sent to the bottom." Now this is what we have always advocated. The power of a ship to withstand the attack which it is likely to meet does not consist in the aggregate weight of armor which it carries, but in the disposition of that armor. The small iron-clad which Mr. Scott proposes to build would be somewhat similar in construction to the "Enterprise" and "Research," upon which Mr. Scott's plan is undoubtedly an improvement. He proposes to construct his vessel with a central fort with curved ends, both the sides and ends being armor-plated to a depth of about 6 ft. below the water-line when the vessel is at fighting draught. This fort is intended to have an iron-plated shot-proof deck, and within its walls are the bases of the guns, ventilating, covering, and funnel turrets. There is to be no side armor before and abaft the central fort. Extending from the ends of the fort and covering the hull fore and aft, at a depth of about 6 ft. below the water-line (fighting trim), there will be a shot-proof armored deck; above this armored deck, and rising with a sheer fore and aft, the hull of the ship is similar to that of an unarmored vessel of war. About 6 ft. above the armored deck (fore and aft the central fort) there is another deck of thin plate, the space between these two decks being divided into watertight compartments, which would be in

communication with the ship's pumps, and there would be wing spaces between these compartments and the top sides of the ship, which would afford facilities for stopping shot holes or repairing damage sustained in action. Above these compartments (which Mr. Scott calls the deck tanks) and at a minimum height of 7 ft., is the upper or spar deck, and the space between this deck and the tank deck affords accommodation for officers and crew when the ship is out of action. It will be seen from what we have above stated that a ship built upon this principle would be comparatively light at the ends—a difficulty hitherto experienced in the construction of iron-clad ships. Another advantage which Mr. Scott's ship would possess over a "breastwork" monitor would be the larger area embraced within the central fort, thereby affording increased facilities for working the turrets and guns.

We now come to another important feature in this ship. For every day that a ship is in action she is years out of action, and therefore it becomes a question of great importance that the crew should have a ship which is fit for them to live in. It is, to say the least, not an unimportant matter that a ship should be properly lighted and ventilated, and rendered a fitting floating habitation for men. When fighting at close quarters Mr. Scott's ship's draught of water would be increased by admitting water into the winged spaces and deck tanks, and also between the double bottom of the ship, if built upon the double bottom principle. It will be understood that if the deck of a "breastwork" monitor is penetrated there is nothing to prevent the shot traversing the ship; but in Mr. Scott's ship the armored ends of the fort are carried down to about 6 ft. below the water line, where they join the armored deck fore and aft of the fort, whereby the passage of projectiles is prevented. From what we have briefly stated our readers will see the advantages which Mr. Scott believes he will gain by this system of construction.

Small iron-clad ships carrying one or two big guns are required to render the British fleet perfect. At present we have no such ships. We have seen how powerless the French fleet has proved in the Baltic. We have also seen how this great fleet of heavy ships has been teased and worried by one or two small vessels with a big gun or two on board. It is impossible to build a ship of small dimensions which shall be entirely plated with armor of sufficient thickness to resist the fire of modern artillery; all we can do is to protect in the best manner possible the vital parts of a ship, and we shall be glad to learn that Mr. Scott's plan has been favorably received by the Admiralty.

ON THE PROCESS OF INCLINING A SHIP IN ORDER TO FIND HER CENTRE OF GRAVITY.

From "The Engineer."

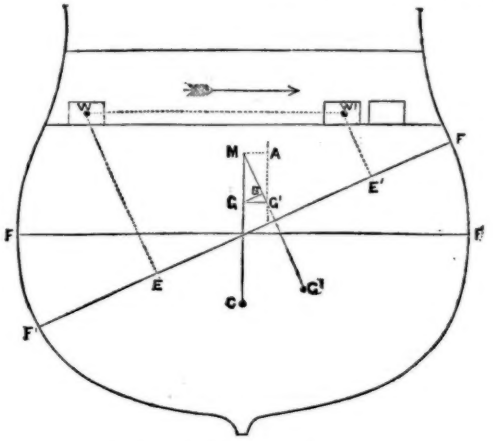
Questions connected with the stability of ships have recently attracted so much attention that we feel sure the following paper will be appreciated by readers of "The Engineer." We have in it explained as simply and plainly as possible the *rationale* of the entire process of inclining, as practised in her Majesty's dockyards and elsewhere. The method of finding experimentally the position of a ship's centre of gravity, by measuring the angle of heel produced by a given alteration of the distribution of weights on board, has been known for nearly a hundred years. It is described in various treatises on naval architecture. Its practical introduction into Britain, about 1830, is due to Mr. Isaac Watts, C. B.

Full details of the process, illustrated by several examples from actual experiments on ships of the British navy, are given in a paper by Mr. F. K. Barnes, in the "Transactions of the Institution of Naval Architects," for 1860.

The principles on which the method depends, are the two following: 1. When a body floats in a steady position, the centre of gravity and the centre of buoyancy are in one vertical line. 2. If the centre of gravity of any part of a body be shifted in a given direction through a given distance, the centre of gravity of

the whole body is shifted in a parallel direction through a distance smaller than the given distance in the same proportion in which the weight of the shifted part is smaller than the weight of the whole body. The centre of buoyancy of a ship coincides with the centre of gravity of the mass of water that she displaces; and its position is found by well-known processes of measurement and calculation, when her lines and the position of her plane of flotation are given.

The experimental operations to be performed when a ship is inclined, are the following: The ship is in the first place trimmed so as to float upright, all heavy bodies on board being secured so that they cannot shift of themselves when she heels. Then some part of her lading (such as guns or pig-iron) is shifted in a transverse or thwartship direction, so as to make her heel over; the weight of each shifted mass and the distance through which it is shifted, being carefully meas-



ured and noted. The angle to which the ship is steadily inclined or heeled over is observed by the help of suitable instruments; and for this purpose it is usual to fit up plumb lines and scales in the hatchways.

The processes of drawing and calculation are as follows: Let the figure represent a body plan of the ship, and let FF be her plane of flotation, and C her centre of buoyancy when in the upright position. Then it is known that her centre of gravity must be situated somewhere in the vertical line CM, which traverses the centre of buoyancy; for that is the line of action of the resultant upward pressure of the water, by which the ship's weight is supported. Let F_1 F represent the plane of flotation when the ship is heeled over to the angle observed during the experiment, and C' the corresponding position of the centre of buoyancy, found by measurement and calculation, according to the rules already mentioned. Then C' M, perpendicular to F' F', will represent the new position of the line of action of the resultant upward vertical pressure of the water; and the centre of gravity of the ship, when in her inclined position, must be situated somewhere in this line. Multiply each of the shifted weights by the distance through which it was shifted transversely during the experiment, and add together the products. For example, let W be the position of one of the weights when the ship was upright, and W' the position to which the same weight was shifted in order to incline her; then multiply the weight W by the distance $\overline{W\,W'}$, and add together that product and all the corresponding products for the other shifted weights. Divide the sum of these products by the whole weight of the ship with everything on board; in other words, by her displacement. The quotient will be the distance through which the centre of gravity of the ship was shifted transversely during the experiment.

Let M A represent that distance, laid off transversely, that is, parallel to $\overline{W\,W'}$,

from the vertical line C M. Through A, and parallel to M C, draw A G¹, cutting M C¹ in G¹. This point will represent the centre of gravity of the ship when in the inclined position. Then through G¹, and parallel to $\overline{A M}$ and $\overline{W W^1}$, draw $\overline{G G^1}$, cutting C M in G; this point will represent *the centre of gravity of the ship when in the upright position.*

To find by calculation the depth M G of the centre of gravity below the point of intersection M of the two lines of upward vertical pressure, C M and C M¹, multiply the calculated distance $\overline{G G^1} = \overline{M A}$ by the cotangent of the observed angle of inclination, C M C¹.

At small angles of inclination the point M sensibly coincides with the metacentre, whose height C M above the centre of buoyancy in the upright position may be calculated from measurements on the plans, so as to avoid the necessity of determining the centre of buoyancy C¹ in the inclined position. The same is the case, even at large angles of inclination, provided the ship is of such a figure that the intersection M does not sensibly change its position as she heels over. This property belongs to most of the ordinary forms of large ships, but not to those which either flare out or tumble home to an unusual extent, or which heel over so as to immerse the gunwale; and in them the position C¹ of the centre of buoyancy, when inclined, should be found by special measurements and calculations.

The statical moment of the forces by which the ship is inclined, and the equal and opposite moment of the forces with which she tends to right herself, may be calculated either by multiplying each of the shifted weights W by the projection $\overline{E E^1}$, on the plane of inclined flotation of the distance through which that weight was shifted, and taking the sum of the products; or by multiplying the displacement of the ship by the perpendicular distance, G B, of her centre of gravity when she is upright, from the line of action, C¹ M, of the resultant upward pressure of the water when she is inclined.

TECHNICAL EDUCATION—THE RENSSELAER POLYTECHNIC INSTITUTE.

(*Continued from page* 13.)

When a graduate leaves school and goes to work in any department of engineering into which the mechanical element largely enters, such as constructing and erecting machinery, mills, engines, buildings, bridges, and fixed plant, his very first step and every succeeding step call for ready and accurate knowledge on the following subjects:

1. On the use of mathematical processes and instruments.

2. On the theoretical strength and stability of materials and structures, or the application of mathematical formulæ to certain known shapes and properties of materials.

3. On the mechanical powers.

These are so thoroughly taught at the Rensselaer Institute, that little improvement is at present possible or desirable.

4. On the principles of prime movers.

5. On the fundamental principles of the mechanics of solids and fluids.

6. On the fundamental principles of Physics.

These subjects are certainly the basis of any reasonably thorough engineering education.

The important question now arises—are these the only, or even the most important elements of practical education that are *attainable in a school*, considering the nature and scope of the professional problems of the period? Is this all that can be practicably taught by books and lectures? To answer this question, let us examine in detail several of the more important problems that the graduate has to face the first day he begins practice. In whatever branch of engineering he commences, whether in mining, machinery, tools, fixed works, transportation by land or water, metal working, water supply, or agriculture—whatever part he may take in utilizing the forces and materials of nature, his right hand ally is the *steam engine.* In the present state of mechanical and constructive arts, steam power is the rule and all other prime movers are the exception. Animal power is too slow

and costly even to dig in a bank or to carry a hod, in large constructions; wind power is too fluctuating to propel coals from Newcastle to London, and water power is rarely availably situated. We hardly realize, until we stop to reflect, how universal are the offices of steam power. Not only is it the essential principle in transportation and manufacturing, and a part of the permanent works wherever force is artificially applied, but it is the essential motor and tool in mining, construction, erection, agriculture, and the preparation of materials. Wherever there is work to do, in the bottom of a shaft, under the bed of a river, in the air, under water, afloat, ashore, in the elaborate water-works of a city, in the farmer's barn-yard, driving a ship's screw, hoisting bricks and mortar, blowing a furnace, hauling a plough, sawing boards, digging for foundations, making watches, laying masonry—in short, in preparing, transporting, and putting together the materials in every branch of construction and manufacture—for all these purposes the engineer must be prepared, not merely to set up a steam engine just as if it were a brick or a fence post, but to select or to adapt a steam engine and boiler with reference to first cost, economy of fuel, available space and convenience of maintenance, and to the particular kind, amount, and duration of the work to be done.

Looking at the steam engine in this light, which is certainly the proper way to regard it in these days, it is difficult to believe that there is any professional subject, except the use of mathematics, upon which the engineer needs more accurate and varied information. And yet, the principle upon which steam engineering is studied in our schools is, that if a graduate can calculate the ultimate strength of parts and the general dimensions of one text-book type of engine—usually an extinct type—all other attainable knowledge on this subject is of the practical kind, that must be picked up in the shops, as experience or subseqent investigation reveal it.

The argument against teaching what is called practical engineering, in schools, is that we cannot expect to make machinists, contractors, and experts in specialties, during a four or five years' university course; that students have neither opportunity nor time to follow out consecutively, in machine shops, iron works, and engine rooms, the various operations by which a thorough knowledge of steam engineering, for instance, can be acquired; that experience is not merely a substitute for books, but that it is an indispensable element in working knowledge. All of which is true, and should be specially commended to the managers of technical schools where working in a small machine shop is a part of the curriculum.

But this objection does not meet the case under consideratio... Continuing the illustration of the general subject, by means of the steam engine, we find the following branches of knowledge, in addition to mathematics, necessary to an intelligent, judicious, and economical employment of that agency, in the various cases likely to arise in the practice of any engineer.

1st. An intimate knowledge of the mechanical theory of heat, and familiarity with the formulæ and physical conditions necessary to draw practical conclusions from it.

2d. The law of the expansion of steam; with reference to condensation by expansion, compound cylinders, high piston speed, super-heating, clearances, and the lap, lead, motion, and other functions of valve gear. A student may as well know nothing about the law of expansion, as to know it independently of these conditions.

3d. The law of combustion, not merely as a laboratory experiment, but with reference to available room, time, furnace materials, and fuels.

4th. The law of the flow of fluids and gases, with reference to changes of temperature, distances, and initial pressures.

5th. The laws of the expansion of metals, not merely abstractly, but under the ordinary conditions of temperature and friction.

6th. The laws of friction, reference being had to the conditions of service,—that is to say, afloat or ashore; in a dusty rolling mill, or in a clean engine room; and the possibility of extra stress, as in locomotives.

7th. The relations of heating-surfaces of different kinds and in different positions relatively to the fire and to the gas currents; and of grate surfaces and openings with respect to different fuels; and

of water spaces, circulation, separation, and steam room, for various kinds of service.

8th. The principles of calculating power and of making allowances for frictions, condensations, and losses, by means of formulæ, indicator cards, and water and fuel used; and also, of determining the dimensions of boilers, condensers, cylinders, etc., from estimated power.

9th. The principles of calculating the power required for different purposes, such as for propelling mills, machines, and vessels of given shapes, and also the principles of constructing and determining the results of dynamometers.

10th. The character of materials used in construction—not merely their ultimate strength, but their adaptability to particular uses, with reference to temperature, moisture, friction, expansion, and working stress of all kinds.

The improvements which have, since text-books were written, entirely revolutionized the economical use of steam power; the new discoveries, inventions, and adaptations which characterize the modern steam engine, are chiefly founded on the knowledge of the laws here stated, and upon such knowledge further improvements are likely to proceed. This is especially true regarding heat, in the various phases in which it is dealt with by the steam engineer—expansion, condensation, combustion, etc.

Nor is this knowledge available only with reference to the steam engine. The laws of heat, combustion, friction, expansion, the flow of fluids, the estimation of power, and the nature of materials—not merely in the abstract, but as they are encountered in practice, are of universal application.

Yet these are the branches of knowledge which are least thoroughly taught in schools. Some of them are not even alluded to throughout the course, and must be acquired, if at all, when the necessity arises for their use, which is immediately upon graduation; and they must be acquired, to a great extent, by the same means and processes that would be employed in a school, for they are all, or nearly all, of such a character that no mere practice or experience can impart them at all, or even make place for them, without great waste of time. In short, the greater part of the existing knowledge on these subjects is to be found in the professional literature, and may therefore be imparted to students in lecture-rooms. It is not indeed found in the text-books at present standard, but it exists in a shape that can be reduced to the didactic form without great difficulty. The *means* of imparting this knowledge will be considered in another part of this report.

Your committee are of the opinion, in view of the universal application of steam power, of the great variety of conditions under which it must be used, of the immense amount of positive knowledge that is recorded on the subject, and of the adaptation to general purposes of the laws which govern steam, that the degree of Engineer should not be conferred upon the graduates of a high technical school, unless it is founded upon at least a respectable acquaintance with the subjects above enumerated.

Your committee do not underrate the importance of experience; of that practical judgment which books cannot give; of the many and invaluable teachings which nothing but repeated personal failure can impart; of those ideas which enter the brain through the fingers; of that imperceptible education of the senses; of that sympathy of the man and the machine which is akin to the sympathy between the members of the human body—of all that varied and invaluable knowledge which, without necessarily imparting skill, rounds and harmonizes the education of the engineer.

Nothing can be more injudicious—no feature of technical education in schools is more injudicious, than the idea, imparted or implied or uncorrected, that the instruction derived directly from workmen, from materials and from machines, in the workshop and in the field, is of a lower grade than that imparted in the academy. If the choice lay between these two methods of instruction—if the one or the other must be abandoned, the skilled laborer, graduated by the district school, and perfected in science by his weekly technical newspaper, would perhaps make a better record than the most elaborately finished bachelor of text-book engineering. The intelligent and ambitious mechanic almost inevitably stumbles into enough theoretical knowledge to

carry out with confidence, independence, and commercial success, some department of construction or manufacture. But the mere theorist—the student whose text-book culture has not been illuminated, and, so to speak, incarnated by constant reference to and dependence upon practice, rarely acquires in after-life the counterpart of a *working* education. Mere mathematicians and scientists often form a part of a thriving engineer's plant and machinery, and however valuable their functions may be to *him*, they do not often acquire reputation and fortune for themselves, in connection with great engineering works. The history of engineering affords many illustrations of this fact.

These considerations indicate that an engineering education cannot be *completed* by books; but their more important, and, we fear, less appreciated lesson is, that the culture imparted by books, should have intimate relations with the best, the latest and the current practice.

The knowledge which enables a man to practise mechanical engineering, classified according to the methods by which it may be acquired, is of three kinds.

1st. Theoretical, so called, or, more properly, *rational*. This, whether acquired in schools or in the intervals of practice, is attained by the same methods and from the same sources.

2d. Practical, so called, or more properly, *experimental*, which is the result of practice and experience alone.

The third kind partakes of the theoretical and the practical, and cannot be successfully acquired without constant referenge to these co-ordinate means of instruction.

There is no difficulty in distinguishing between the first two departments. The difficulty is that the schoolmen do not classify technical instruction on this principle. According to their classification, the proper subjects for academic culture are those that are embodied in text-books. All the rest is thrown over into the post-graduate course, under the general head of practice.

Now the notorious fact is, that there are no recognized text-books of what may be called modern mechanical engineering—of the steam engine of the period, of steam agriculture, of the sewerage of towns, of naval architecture, of the present machinery of offence and defence, of steam on canals, of permanent way, of mining and excavating machinery, of iron buildings, of storing and utilizing the power of wind and tide, of the new system of railway practice known as the "light railway" and "steam carriage" system, of modern pumping, hoisting and blowing machinery, of the machinery for accumulating power and transmitting it through long distances, of roll trains, steam hammers, and the iron working machines of the day,—of modern engineering in general. There are no text-books on these subjects, but there is a very comprehensive literature, a definite practice, and a teachable science. These are the subjects which will involve three-quarters of the capital, the talent, and the professional learning of the coming years, and the first thing the graduate of a technical school has to do after being solemnly labelled "Engineer" on commencement day, is to learn the theory of his business—to again place himself under a course of literary instruction. In some instances known to your committee, the graduate has actually to unlearn the antiquated and superseded lore of the text-books. The principles of constructing, arranging and proportioning steam engines, for instance, as taught in certain technical schools, are positively noxious, and all those improvements that characterize and define the modern steam engine, such as expansion in double cylinders, surface condensation, super-heating, and rapid cut-off, are entirely ignored.

There are no text-books, in the English language, of pattern-making, founding, forging, finishing, and of iron and wood working machinery. Engineers need not, indeed, acquire skill in these departments, but a knowledge of their principles and capacities is absolutely indispensable, and can be acquired in a school, by the aid of drawings and models, much more comprehensively and harmoniously, in a given time, than by actual practice. This class of instruction will be again referred to.

Your committee are of the opinion that the importance of imparting the most modern and practical information is fully appreciated by the Faculty of the Rensselaer Institute, and that the want of a sufficient number of instructors and of time and place in the course of study, for the modern branches, is their chief embarrass-

ment. The general theory, however, obtains, in all our technical schools, that the information they are to impart, is chiefly that derivable from books written for the express purpose of academic instruction. The idea of selecting parts of the standard technical books and monographs—of courses of reading and examination in the technical serials, and of lectures and examinations founded upon the current literature and practice, is not entirely novel, but it is revolutionary, and will be farther considered.

Your committee do not forget that one of the chief offices of any system of study is intellectual drill—training the mind in the processes and habits of work. It appears merely to suggest, under this head, that if the purely mathematical part of the course is not rigid enough in this direction, the problems of mechanics, chemistry and physics, are sufficiently abstruse for all purposes of mental culture.

With regard to the third division of engineering education—that which is derivable from books and oral teaching, constantly illustrated by and referred to practice, there is a variety of opinion. The subjects that we have so far considered, are as purely theoretical as are the calculations of the strains in a bridge. There is no question about the proper method of teaching these subjects. They are, indeed, distinguished from ordinary theoretical studies, not however by being founded on practice, but by being founded on modern and current practice.

We now come to a department of education, into which the experimental element must largely enter. Is it practicable to teach it, or the rudiments of it in a school? Is it not even better that the practitioner should study theories in the intervals of practice, than that the student, already crowded with new theoretical studies, should take the necessary time to learn, or rather half learn, the practical part, in the places where construction and manufacture are going on? Is not the legitimate function of a professional school simply to train the student in the intellectual tools of the profession? This is the theory that usually obtains; but there is a widely different system already in use, at the Washburn school in Worcester, for instance, and about to be introduced at the Stevens school in Hoboken. These institutions embrace a working machine-shop among the apparatus of instruction.

It appears to your committee that a four or five years' course is already so crowded with theoretical studies, that the addition of a course in skilled labor would be impracticable, even if necessary. Only a small part of the practical training of the engineer can be obtained in a machine shop. Were an iron-works, a railroad and a steamship added to the plant, and another five years to the course, the graduate of such a school would doubtless be better trained than the ordinary graduate of five years' standing. Such an establishment would of course be impracticable, and it is possible that the students in a machine-shop institute, being constantly told that they were learning practice as well as theory, would become narrow and limited in their ideas, and would attach insufficient importance to the counterpart of their education yet to be derived from the business pursuit of the profsssion. In short, such schools seem to be rather industrial than scientific.

But there is an intermediate class of knowledge, which has been imparted, as yet, on a very limited scale, in American schools. The extent to which it may be, and should be, taught in schools, is best explained by an illustration. In every machine and engineering structure, a certain element of stability has to be provided for, in addition to all those resistances to the measurable strains that can be calculated by rule and formula. Excessive amounts of material must be put into various parts, such as bed-pieces, simply to provide inertia—to prevent trembling and chattering. There is no rule for such cases; in perfected machines, these proportions have been taught simply by repeated breakdowns, and in newly designed machines, they are usually a matter of judgment; experience alone can fit a man to provide for them. But should not the graduate know beforehand, that he must encounter this problem? It is not practicable, by means of a lecture or two, even to give him a general idea of its nature, illustrated by a comparison of the actual with the theoretical dimensions of parts subject to vibration, in standard machines? Half an hour's explanation, aided by a few drawings and calculations, will give a whole class such an idea of this

element of design, that they will at least know that they have got to know more, and when and where to look out for it. These preliminary hints, save not only time in acquiring farther information, but they may save money and lives, by warning young designers of danger ahead.

This is but a sample of the many practical problems which must indeed be worked out in the field, but of which the pass word can be given in the recitation room.

Pattern-making, founding, forging, plate working and the capabilities of machine tools, rolls and hammers, are not even referred to in many schools that profess to teach engineering, and the reason given by the schoolmen is, that the object of a school is not to make artisans to execute, but engineers to design. Now it is a notorious fact that the machinery first designed by graduates, contains pieces that can neither be cast, forged, rolled, fitted up, put together, taken apart or repaired with any reasonable economy, if at all. We do not expect inexperienced men to compete with established practitioners, and we do expect designers, however learned, to consult with expert artisans as to the details of economical execution. But is it too much to expect one more thing, viz.: that a graduated engineer shall have some idea of what tools will do and what they will not do; of what can and what cannot be executed; of the functions and capabilities, not only of the things made, but of the things that make them? If a graduate has no ideas on these subjects, he is still a student of theory; after he begins practice he cannot be trusted with any detail of design or execution; he must be constantly watched; he is a mere copyist or tool till he has mastered the rudiments of these subjects; and as his education is not the object of his employer, he is not taken about and lectured and drilled and corrected and examined and made to understand these things. He gets his rudimentary knowledge of them by the longest, the hardest, and the most roundabout course, and it is in acquiring these rudiments that the neophyte meets his most serious delays and embarrassments. They are easily enough acquired when they are specially pointed out, and their development and application follow upon practice, as a matter of course. But they are not specially pointed out. It is a common and serious mistake to suppose that mere employment in engineering work is of itself a systematic and comprehensive course of instruction. For the very want of this rudimentary knowledge, the novice is usually kept in a groove where he can be made useful; no instructor is appointed to tell him what things outside of that groove he ought to learn, or how and where to find the information. He has to establish his own curriculum and be his own schoolmaster. There is no professor watching over him, to show him what to study and to see that he learns it. A man may be a draftsman, or a mathematician, or an assistant in one or two deparments for years, and yet have so limited a knowledge of the capacities of tools, materials and processes, as to be unable to design and execute independently—on his own account.

Now cannot our schools, instead of giving their graduates no hint on many of the subjects they will inevitably encounter before they can earn a living—cannot our schools say to their students: "We cannot give you experience, nor judgment, nor mechanical instinct, but what we can do is to smooth the way and shorten the course? We can at least prevent your groping in the dark after knowledge or going for years without it because you do not know what kind of knowledge you want and where to look for it."

Sending men out of a school, full of mathematics and text-book science, but ignorant of even the existence of the coordinate branches of knowledge yet to be acquired, appears very much like sending a ship to sea without a chart. The school furnishes its offspring with an engine, a rudder and a compass, and then says to him: "Now be off—you have many ports to make, and when you find them, you'll know where they are!"

Your committee are aware that these considerations are unorthodox, if not revolutionary, and that if they should appear plausible, they should not be adopted hastily or without more extended investigation. But when your committee see all over the country, mechanical engineers without remarkable talent, without any culture except that derived from the common school, the professional newspaper and practice, executing important works and making great names and fortunes,

and when they see in the drawing-rooms of these very engineers, men of equal natural capacity, who *have* been labelled experts, and who for the want, not of experience, but of a ready guide to the fruits of experience, are for another four years or more, simply copying and calculating *machines*, they cannot avoid the conclusion that there is a missing link in the present system of technical instruction. It is a general fact, that not until after as many years of practice as are required by uneducated men, do the graduates of our technical schools achieve the positions due to their advantages.

Should it appear desirable to modify the curriculum of the Rensselaer Institute in accordance with these suggestions, the question arises, by what means is it to be done?

In the absence of text-books, it must evidently be done by lectures founded on the modern and current practice, and illustrated by models and drawings, by courses of reading in technical publications, and, as far as time will permit, by a sufficient examination of works and processes in progress, to explain and utilize the theoretical instruction—and finally, by as rigid a course of examination in the knowledge thus imparted, as in any other department.

The first difficulty would appear in providing time for such a variety of instruction. But this difficulty diminishes upon examination. Those studies last considered, which may be called *guides to practical studies*, although large in scope, do not purport to cover all the cases that may arise, but to group the more important ones into classes, and to illustrate each class by going into detail with a few representative cases. For instance, in a single lecture, the whole subject before alluded to, of vibration as affecting the stability, wearing out, and capacity of machines and structures, could be sufficiently elucidated for this purpose. A number of cases would be mentioned under the head of *remedy by elasticity*, such as placing wooden cushions between the parts of a steam hammer frame, and under an anvil block, and between the tyre and rim of a locomotive wheel, and in an iron railway sleeper, and generally, where there were sudden shocks, and where at the same time no objection existed, such as getting accurate machinery out of line. This class of cases would be illustrated by a short specification or two, of proportions and arrangement with reference to load and stress. Another class, under the head of *remedy by stiffness and inertia in detail*, would be illustrated, after a general reference to the principal examples, by the steam engine, in which not only the bed plate but the connecting rods, the shaft, and other parts stand in such relation to the strains, that no mere mass in the foundation piece will answer the purpose; in which, especially when portable or locomotive, great weight is inadmissible and stiffness must be obtained by bracing; and in which the rigidity required to keep the machine in line, and the absence of violent shocks, render elastic media improper and unnecessary. A third class would be illustrated by the machine tool—the lathe and planer, in which the stress is of such a character that mere mass and inertia in the framing are indispensable, and elastic media are harmful.

Lectures on this plan should be carefully prepared after consultation with the best practitioners, and should be followed up by a rigid examination of the student, not only on the cases considered, but on the principles involved. In such cognate subjects as bearing surfaces, the convenience of taking machines apart for repairs, lubrication, boiler-setting, lining or adjusting machinery, temporary hoisting gear, blocking and false work, pipe-fitting, pattern making, the principles, capacities, and economies of foundries, machine tools, special tools, forging, plate and sheet-iron working, the behavior of metals, woods, and materials under stress of heat and moisture, and their qualities, grades, brands, and sources of supply; and some rudimentary ideas as to the value of materials and labor, and the commercial forms for obtaining them—these and some other practical subjects may be not only mapped out, but they may be so far explained and impressed by one lecture apiece, that the graduate will know just where and how to learn more. Probably twenty lectures, or say one month, devoted to this class of subjects, would save the graduate many months of delay and disappointment in his early practice.

Another class of lectures, of a theoretical character, would be more exhaustive, and hence would require more time. Their

subjects have been already indicated in some detail. Such lectures should, of course, be made up from the best technical publications, corrected by current practice. Each lecture should probably be brief enough to be fully copied from dictation by each student; the reading of certain illustrative sections or articles in books, papers before learned bodies, and engineering magazines, should be prescribed; and the examination should cover both the lecture and the reading. The whole mass of professional literature thus becomes the text-book; but only a specified portion of it need be read. The lecture would be both a guide to the readings and a recapitulation of their teachings.

It is probable that lectures on the subjects specially requiring such illustration, should be clinical—that is to say, delivered in the shops and on the ground where work is going on. This plan presents some difficulties in respect of time and opportunities. A great deal of illustration can, however, be accomplished in a very short time, if the lectures are properly adapted and the accompanying drawings are numerous and intelligible. A class may wander about a machine shop or a rolling mill all day, and learn absolutely nothing; while if their minds are prepared, if their interest is awakened, and their attention is concentrated on the particular detail or function to be elucidated, a single look and five minutes talk may produce a sufficient and lasting impression.

Too much importance, however, may be attached to clinical lectures, and to the spending of undergraduate time in the shops. The *working drawing* is the professional language of the engineer, written in short-hand. He builds from drawings works that he has never seen; more than this, he builds from drawings works that have never previously existed. From a set of sections, elevations, and details, the best attainable knowledge of most machines and engineering works may be obtained—better, indeed, than from the works themselves. The rapid reading of drawings is not the highest attainment, but it is the most useful accomplishment of the engineer, and for the purposes of education as well as practice, should be the first and the most thoroughly acquired. Such lectures, then, may not only be well elucidated by drawings, but they may, in addition to the particular illustrations conveyed, perfect the student in the most useful art of his profession.

Tracings from the working drawings of all the best works and machines are not difficult to obtain. Almost any establishment would furnish them at cost, to a school; many establishments would present them; others would lend the originals, and the students might copy some of them for the school, while acquiring the manual part of the art.

Models are of course important; there is hardly a limit to their usefulness, and in some departments they are indispensable. But where types of the works themselves are within reach, and drawings are full, a large museum of models is not absolutely essential.

Your committee fully believe that such lectures, readings, and examinations, illustrated by standard and numerous drawings, and as far as may be by models and originals, are the only practicable method of imparting at least a third part of the information that the graduated mechanical engineer ought to acquire in a school. The place and extent of this part of the course, your committee could not undertake to specify at this time, or without the advice of the Faculty.

The remaining and apparently the most difficult question is: How are such lectures to be provided for? Who is to give them and how are they to be paid for?

A single professor of mechanical engineering would not be able to prepare and to teach the whole or even the half of the course. He would not have time to make all the necessary selections from the current and standard literature, either for his lectures or for the reading of the students; and probably no individual, certainly no one who could be secured, has had both theoretical learning and practical experience, on a sufficiently comprehensive scale to fit him for all these varied duties. Besides, as has elsewhere been shown, half the time at least, of such a professor, would be devoted to aiding the present corps in the enlarged teaching of the old and some of the new branches to the students at large. A professor of mechanical engineering should probably take the general charge of the course, in

as far as it was not coincident with the course in civil engineering and with the studies common to all courses, and he would teach the more general branches of his specialty, such as heat, the laws of the expansion of steam, etc., both by text-books and lectures.

The other theoretical branches hereinbefore enumerated as being essential to the course in mechanical engineering, and also those referred to as guides to the practical studies, would have to be taught by *non-resident professors*—by men actually engaged in the constructions and operations to be investigated. Not every practitioner could prepare the required lectures, however well he might execute the actual work, but the number of experts who could is very large. Such men, by giving one lecture each, on some branch to which their reading and practice had been specially devoted, would hardly miss the time taken from their own pursuits, and would add immensely to the value of the course and to the renown of the institution. Such a lecturer need not necessarily be a teacher by nature or by profession, although it would be better that he should assist in conducting the examinations upon the lectures. But if he would simply read a plain, comprehensive statement of the facts and principles in the case, stripped of all that unpractical, superfluous matter *which experts only can avoid*, the professor having charge of the course could conduct the examination and assist in the merely didactic part.

Many such men do devote, every year, without pay, an equal amount of time to the preparation of papers before professional societies, which are but schools of a higher grade, and these papers are on the whole the best didactic literature of the post-graduate course.

Your committee have little doubt that if a proper effort were made, a dozen eminent or at least capable and growing engineers could be found who would be willing to devote enough time during the next six or twelve months for the preparation of say three lectures each, and who would then be willing to spend one week per year in Troy, at appointed times, to deliver them and to conduct the examinations—and to do this either without pay, or for merely nominal pay and their expenses. * * * *

The missing link between theory and practice, however, is not characteristic of the course in mechanical engineering alone, as administered in our technical schools. We are prepared to reiterate the views thus fully expressed above, with suitable modifications, in regard to the course in civil engineering. What practical or technical studies, and guides to practice, could be advantageously introduced into this course? We shall merely mention, the best *modern practice* in bridge construction, building of all walled structures, public and private, permanent way, canals, foundations, reservoirs, water works and water supply, sewerage, drainage, retaining walls, grading, dock construction, subaqueous engineering, tunnelling, excavation, transportation, lifting and transference of heavy weights, the character of materials, their sources, qualities, imperfections, special adaptations, etc. But there is one class of subjects, of which, above all others, it is highly essential that the civil engineer should have a comprehensive knowledge, and without which he is fairly disqualified to practise his profession, and that is machinery. Surely it is not too much to say that the civil engineer is a mere user of machines, and is bound to know the value, structure, economy, and capacity of his tools as truly as the hand mechanic of the workshops. We by no means urge that his knowledge should be as highly specialized, or as detailed, as that of the mechanical engineer; but that up to a certain point it should be as thorough and practical and available.

Leaving here the civil engineers, and turning to the mining engineers, we may ask, what is one of the latter good for who has no knowledge of the multifarious forms of pumping machinery, the steam engine, hoisting apparatus, boring apparatus, and the numberless mechanical appliances of his trade? These classes of machinery are not mere heterogeneous masses of wheels, cranks, gears, shafts, and iron frames, but they are embodiments and expressions of fixed principles, capable of being classified with reference to definite ideas, laws, and plans, and hence capable of being taught; and where can their principles and the generalities of their practice be taught so economically, comprehensively, and speedily, as at a technical school?

Need anything more be said to demonstrate the immense importance of a course in mechanical engineering to the other courses already in existence? It is possible that there are those who believe that a civil engineer may practise his profession properly without this knowledge, but the members of your committee, as practical men, know nothing about that kind of engineering. The conversations which the committee have had with graduates and practising engineers, in numerous branches, and also the letters of many of their correspondents, are full and ample authority for the assertion that the establishment of a mechanical school upon a basis similar to that proposed, would almost entirely remove the cause of complaint before adverted to. That it would attract to the Institute many students, we cannot doubt, knowing as we do the sentiments entertained by eminent machinists and manufacturers respecting the value of educated assistants and superintendents. To many of the students themselves such a course presents peculiar attractions, and even of those now graduated as civil engineers, many would have preferred the mechanical course had it been at their option.

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The present organization of the Institute includes a programme of studies in natural science. It may be well to note the fact that the Rensselaer Polytechnic Institute was originally founded as a school of science, and has drifted away from its original scheme into a school of the useful arts. This has been compulsory, and not a matter of inclination. Although there exists in the minds of many the desire to re-establish this noble school, your committee are compelled to report against any outlay of money beyond that which is already appropriated annually for the purpose, unless it be some inconsiderable sum necessary to accomplish an efficient prosecution of studies already in vogue. Your committee mean that they cannot recommend any establishment of this course upon a wider basis than the present one, though they are prepared to submit some suggestions respecting its conduct as at present organized. They are aware that by this recommendation they are opposing the wishes of many friends of the Institute. They are also aware of the high value of such studies in effecting scientific culture, and acknowledge the frequent importance of their practical applications. But the position taken with respect to them is entailed by the hard necessity of straitened means and utterly inadequate resources. To establish a distinct department and school of natural science upon a respectable basis would render necessary the building and stocking of museums, the collation of a vast and peculiarly expensive library, and the maintenance of a large additional corps of very expensive instructors, requiring an endowment of hundreds of thousands of dollars. Even then we should have the well-established reputation of Yale and Harvard to contend with before we could expect to draw patronage. Your committee therefore dismiss the idea of an expanded school of natural science without further comment.

But a certain proportion of study in natural science your committee consider indispensable to the engineer. First, however, let us define our view of the meaning of the term *natural science*. In the recent classification of the sciences, it is not held to include either chemistry, astronomy, or physics, which belong to the great class of *physical science*. It does include botany, zoölogy, geology, and mineralogy, or those branches which relate to the structure, classifications, and natural functions of organic and crystalline formations, as found in nature. Of these branches it is difficult to say how much is really essential. Of botany and zoölogy, probably very little is absolutely requisite. It will, perhaps, be sufficient, and certainly will be all that is now practicable, if instruction be confined to the larger clas ifications of animals, plants, and minerals, and the principles upon which those classifications are founded. This is rather indefinite, it is true, and may mean much or little, according to the construction various people are inclined to put upon it; but the limits will have to be fixed by the amount of time available for their instruction. The student who would avail most by these studies will, in many cases, be induced by the attractiveness of the sciences themselves, to seek further knowledge of them outside of the curriculum, and if his zeal be sufficient, it will not be difficult for him

to gratify his tastes. It has frequently been noted by instructors, that the natural sciences, by their inherent beauty and attractiveness, call out the enthusiasm of the student to such an extent that he is not content to rest upon the regular instruction, but pursues them independently, as matters of fancy and taste, and in not a few instances, to an extent detrimental to due proficiency in the other prescribed studies.

The subdivisions mineralogy and geology are deemed by the committee of greater importance, though even here they do not deem it essential to educate students to any high state of proficiency. Determinative mineralogy is certainly highly useful to the civil engineer, and indispensable to the mining engineer, who should be able to determine readily the minerals he encounters in practice. Geology, though nominally a single science, is really a group of natural sciences. It includes, in its higher developments, an extended knowledge of the branches, zoölogy, botany, and mineralogy, which are prerequisite to a knowledge of fossils, upon which, in turn, depends the ability to determine the position and relations of strata. It is highly essential to the mining engineer, being a necessary part of the knowledge which is to render him fit for his duties. It is also useful to civil and mechanical engineers, affording them a means of forming opinions upon numberless questions arising in practice. But there is a higher sense in which this science may be made useful to the man who is educated to practical pursuits. It includes, in the most condensed form, the highest degree of that noble culture derivable from the natural sciences, and exhibits them in their philosophical relations as no other form of scientific study can. At once eminently useful in a practical way, and adapted to the highest scientific culture, it seems well suited to supply certain marked deficiencies in the courses of study, and to alleviate their somewhat dry, harsh, and utilitarian character. Still, how far it should be pursued is questionable. Its utilitarian aspect should be kept chiefly in view, and hence we are inclined to think that a thorough course in Dana's Manual, with such extensions by lecture, or otherwise, as shall develop more fully and availably a knowledge of practical and economical geology, will cover all proper and necessary requirements—thus leaving to post-graduate study any farther proficiency which may be necessary for special applications.

The study of the physical sciences is a matter of grave importance. The physical sciences may be divided as follows:—

1*st.* Chemistry.
2*d.* Astronomy.
3*d.* Elementary physics.
4*th.* Higher physics.

Respecting the first subdivision, chemistry, the committee need to say but little. It is one of those comprehensive sciences which lie at the foundation of all the useful arts. Engineers and mechanics are daily called upon to use practically its principles and details. We believe that the efficiency of every section in the Institute depends upon a thorough knowledge of chemistry, almost as intimately as upon thorough discipline in mathematics. But how far each section should respectively pursue the study and experimental practice of chemistry, admits of some discussion. It is clear that the mining engineer should pursue it farther than either the civil or the mechanical engineer; since his profession is, in great part, a branch of applied chemistry. But the other sections should be able to make qualitative analysis, and be thoroughly versed in the general principles of inorganic chemistry. The programme of the Institute contemplates this degree of proficiency, though it has not been adequately carried out. The time allowed for laboratory practice has been insufficient, both to the mining and civil engineers, to accomplish the purposes of the programme, and it is recommended earnestly that, hereafter, sufficient time be allowed to the chemical department, to enable the students to reach the desired degree of proficiency.

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The subdivision of astronomy is one upon which the committee have but one recommendation to make, viz.: that the mining engineers be not required to receive instruction in spherical astronomy, and that their time and attention in this branch be confined to descriptive and practical astronomy. The same recommendation would hold for mechanical engineers. For the civil engineers it may be continued, the present programme being very satisfactory in this respect.

The next subdivision, elementary physics, is one upon which the committee have some suggestions to make. Inasmuch as this is preparatory for, and continuous with, higher physics, it will be proper to discuss them together. The term "elementary physics" is generally understood to include the greater part of what was formerly taught under the name "natural philosophy," from which it differs by no longer including the discussion of the five mechanical powers, the laws of falling bodies, gravitation, hydrostatics, and several other subjects—all of which are now treated under the distinct head, mechanics. While it has excluded these topics, it has taken to itself others, which did not belong to the old system of natural philosophy, viz. : the principles of chemical affinity, of atomic proportions, of the conservation of forces, and, in short, all those definite principles which serve as the basis on which chemistry is built. As compared with mechanics, it may be approximately defined as treating of the effects of forces upon *atoms and molecules*, and the relations of atoms to each other ; mechanics treats of the effects of forces upon *masses* of matter, and the relations of masses to each other. It will therefore be seen to be a fundamental science, upon which a whole class of higher sciences rest —precisely as algebra and geometry are fundamental with respect to the higher mathematics, and arithmetic fundamental with respect to algebra and geometry. Chemistry is the development of physics in a particular direction. The laws of heat, or thermodynamics, is a development in another direction ; optics, or the laws of light, in a third; acoustics, or the laws of sound, in a fourth; electricity, or the laws of polarity, in a fifth, etc. Elementary physics is fundamental, and underlies them all; it is, so to speak, the arithmetic of these sciences.

It will hardly be questioned that an engineer must know, in a general way, the whole compass of elementary physics. But how far should he pursue its special and analytical developments into the higher branches—chemistry, optics, acoustics, electricity, and thermodynamics? It is suggested here that you adopt, as a rule for determination, the measure of utility, and by this rule we think a conclusion will not be difficult. Thus, chemistry has already been adverted to and recommendation made. Optics is a branch on which we think the engineer needs no special knowledge beyond that required to comprehend the general principles involved in the construction of optical instruments, and to be equal to a diagnosis of their infirmities. No refined analysis of the undulatory theory of light is deemed essential. So also in acoustics; it is believed that the engineer will be abundantly able to comprehend the meaning of the fire-bell, door-bell, or dinner-bell without stopping to apply the calculus. Your committee think that these studies, as special extensions of physical science, could be dispensed with. They are taught in a general way, and probably to a degree quite adequate to the wants of students, in the text-books of elementary physics.

The study of the subject of heat, far beyond any degree now contemplated, or taught, in the Institute, seems to your committee worthy of urgent recommendation. It is at once an eminently difficult, profound, and practical subject, and (which is a little peculiar), not only does its utility increase with a refined and thorough knowledge of it, but its true nature and real utility do not become thoroughly intelligible until an advanced stage of knowledge is reached. The fact that heat is now the great motive agent, and that its economy is one of the great aims—perhaps the greatest aim—of modern engineering, are abundant reasons why the engineer should understand it. In consequence of recent discoveries, and the results of investigations in progress, its economy has become a matter of calculation, as perfect and demonstrable as the strains upon the parts of a bridge, or the resistance to moving bodies on land or water; and it is a matter of surprise to the committee that these facts have not heretofore been acted upon in the construction of the programme of the Institute. It is recommended that, in the place of optics and acoustics, the mechanical theory of heat be taught analytically to every section, mining engineers included. It must be mentioned that no text-book on the subject, in the English language, is known to the committee, excepting one or two, which do not seem to be satisfactory. There are, however, several in the French and German, thoroughly admirable in all respects. It has occurred to the committee, that as the

students receive a very satisfactory course of instruction in the French language, it might be advisable for students to use a French text-book on this subject. The committee do not make a definite recommendation to that effect, but merely throw out the suggestion for the consideration of the Trustees.

The subject of electricity is also thought worthy of special development, though its claims are not so imperative as the preceding. It is a branch of physics which is yearly becoming of greater and greater importance. The principles of this subject are usually dwelt upon with considerable minuteness in all text-books of general physics, and in view of the general stringency of the whole curriculum, the committee believe that it will be sufficient, at present, if the text-books of elementary physics be thoroughly and rigorously taught. But it seems that the instruction should be supplemented by lectures and experimental illustrations, since a knowledge of electrical machinery is quite as essential as that of principles, and it is difficult to see how this can be obtained elsewhere than in the lecture-room where the apparatus is at work.

Having thus gone briefly over the department of physical sciences, it will be noticed that, in several instances, increased proficiency has been recommended. On the whole, it will also appear that the committee have attached to these branches much higher importance than those have done upon whom has heretofore fallen the delicate and difficult task of arranging and balancing the various courses. It is readily conceded by the committee that they lack the advantages of judging the relative merits of these questions, possessed by experienced and learned instructors. On the other hand, they have had the compensating advantages of experience in the practical exigencies of the professions for which these studies are preparatory, and, after all, is it not by its adaptation to ends that any instrumentality must ultimately be judged? * * * * *

With regard to the general literary course, it appears to the committee that some advantage would be gained if such studies were distributed over the whole four years, instead of being confined, as at present, to the first two years. This might be readily effected, too, if, as has been proposed, the mathematical and scientific studies be pushed backward into the earlier years. The advantages of such an arrangement become apparent, when it is remembered that *time* is an essential element in literary training. That is to say, more culture will result from a given amount of study and exercise distributed over four years, than from an equal amount extending through two years. By the latter method the student is taught to write before he has developed his capacity to think, or has anything to think about. The true method should be to give him knowledge of *things*, and after that, he will be able to reflect upon them, apprehend their relations, and express them—which is the essence of rhetoric. At all other institutions, English composition and rhetoric begin, after more or less preliminary training, in a small way, and progress with increasing importance, until they become the culminating point of the whole system of academic instruction. This is doubtless the true plan; for the student's capacity to express is thus developed in direct ratio to his capacity to think, and to the amount of material he possesses to exercise his thoughts upon.

The present distribution at the Institute was made in order to accommodate those students who had enjoyed the advantages of a collegiate education, and enable them to dispense with the first two years of the course. It was assumed that such students had already received a thorough literary training, and that it was desirable to have this part out of the way when they were ready to enter. This reasoning is more plausible than accurate. In the first place, the number of collegians who enter the Institute are few in number, not exceeding two or three in each class, and it is undoubtedly better to submit these gentlemen to a reduplication of some studies, than to deprive the others of what is absolutely requisite. In the second place, it is by no means certain that a collegian may not derive very considerable advantages from a properly constructed course of scientific literature. The college graduate represents merely one phase of intellectual culture, and that phase is not merely distinct, but, in some respects, antithetical to that developed here. He represents the classical, the speculative, the abstract; ours the modern, the material, the concrete. He deals with

words about thoughts, and thoughts about other thoughts ; ours deals with words about things, and thoughts about things. He is the contemplative man of letters and philosophy ; ours is the scientific man treating of facts and realities. We raise no question here about the merits of the two systems, but are content to point out the differences. Whatever may be the culture and proficiency of the collegian who comes here, he has yet to learn how to think and write *scientifically*. There is a wide interval between the scientific and the merely literary way of treating a subject, and however much they may have in common—as, for instance, a common grammar, common figures of speech and rhetoric, and a common logical basis—the forms, fashions, and habitudes of the two methods are widely asunder. What should be the general character and scope of the literary training at the Institute, it is difficult to say with confidence ; but it should have for its object the development of a capacity to write upon scientific subjects in a suitable manner.

Respecting the means by which this end is to be obtained, it is suggested that the desired result will depend chiefly upon the personal efforts and determination of the student himself, more than upon books or exercises. No intellectual effort is more exacting of labor, and in none is progress more slow, than in the formation of style and method. The best that can be done is to keep the importance of the subject constantly before the mind of the student, stimulate his ambition, hold up the models before him, correct his errors, and exact general results, rather than good recitations from text-books. Much will also depend upon the instructor. He must have didactic powers far beyond what is necessary to clear up difficulties of text-books. He must be able to put life and enthusiasm into his functions, to sustain the interest and courage of his pupils, to draw out their thoughts, and to keep them constantly thinking. He must also possess general scientific culture, and tolerable familiarity with scientific literature and philosophy.

It seems to the committee that the following plan would contribute greatly to this branch of training ; and having no doubt of its efficiency, they would recommend it, viz.: that the student be required, during the last two years of the course, to prepare frequent essays and discussions upon professional subjects. During the third year, it would perhaps not be well to exact such efforts oftener than once a month ; but during the last year, their frequency should be increased to as often as once in three, or possibly even two weeks. Twenty to thirty exercises of this kind would amount to a fair preliminary training, and ought to give very marked results. Such performances should, by all means, be criticised chiefly with reference to style and method of treatment, and the standard should be tolerably rigid. The range of subjects selected should, as a rule, be confined to matters of detail, and not to largely expanded or broad themes—otherwise the writers will be apt to degenerate into loose, vague, inaccurate methods, and into that disgusting and foolish habit of generalizing, without anything to generalize upon.

Take an instance. Suppose a young man were requested to write a short essay upon crank-pins. Let him take a leisure hour, some afternoon, and visit the excellent establishment of Starbuck Bros. Let him inform the courteous proprietor what he wants, and in a few minutes, he will have learned that a little piece of steel, which might at first have seemed to him as destitute of high mechanical functions as a nail in a board fence, has relations which are intricate, scientific, and pleasing. Let him return to his room, and attempt to systematize his new acquisitions. Do not let him commence with Tubal Cain, nor with the pre-historic Swiss, nor with the tea-kettle, but at a rational beginning. With some little guidance, and some experience, he will be able to produce a concise, clear, logical, forcible little essay, containing more valuable and available material in half a dozen pages, or even less, than has been contained in all the theses to which it has been our questionable privilege to listen from the graduating students of scientific schools. He will have gained at least four things :

1st. Valuable practical information, not merely about one practical subject, and a part of a machine, but glimpses of practical relations to other and dependent parts.

2d. Some idea of what professional practice is, what unexpected difficulties it brings to light, and what kind of tempera-

ment, and what kind of means are requisite to overcome them.

3d. Some experience of a logical way of thinking about professional matters, and of professional insight.

4th. Some experience in putting ideas upon paper, so that when he has multiplied these experiences a few times, and entered practice, and when his employer sends him, as he is sure to do, to make a report upon some new process, or machine, or the details of some structure erecting, or long since erected, in other cities, he shall be able to send back a report, which will save his employer the necessity of going himself, after all.

Your committee have thus endeavored to convey to you the results of their careful investigation into the status of the Institute, and their opinions respecting its courses of study. Their work has been considerable, their reflection long and earnest, and though further insight might still modify their conclusions somewhat yet, in the main, they are satisfied with the general tendency of their recommendations. Throughout their inquiries they have endeavored to keep entirely aloof from all personal considerations—if such there were, which could influence either their judgment or their feelings—and to conciliate all true friends to the Institute. So far as their knowledge extends, they have succeeded in both these objects. That some of the propositions contained in this report may be considered strange and revolutionary; that they may excite distrust among the conservative, and awaken little confidence among those who will not take the pains to ponder them earnestly, we more than suspect. But we beg leave to state that we believe them to be sustained by the opinions of the most talented, promising, and accomplished graduates, and of the foremost mechanics and constructors of the country. Yet these opinions are not so revolutionary as they seem. It must be remembered that a great part of what the Institute must teach, is the reverse of fixed and unchangeable. It does not consist in dead languages, nor in immutable history, nor in changeless codes of law; but in the modern sciences which change their aspects as swiftly as the clouds of the sky, or the spots on the sun. It is the mission of others to treat of that which is fixed; ours, of that which is progressive; and our methods must change with our themes, and our practice with our facts. Nor are we by any means the first to recognize these things. It is the most comprehensive and noble function of European schools to provide for these changes—this fact of mutability and this ceaseless march of progress. The Conservatory of Arts and Trades at Paris, the great University of Zurich, the Schools of Freyburg, Stuttgart, Carlsruhe and Berlin, keep their greatest men in the background, where they devote their energies to this very end—keeping methods of teaching parallel with the requirements of practice, and only nominally, or perhaps never, to lecturing. How then can a school, in this mercurial country, teach the arts of twenty years ago, and hope to make a living by it? * * * * *

The committee have felt it to be their duty to speak strongly and earnestly on many subjects, which in the present methods and balance of the Institute, as well as of American technical schools in general, have met their disapprobation. But in so doing they wish to be acquitted of any intention to find fault with the present faculty. On the contrary, they warmly congratulate the Trustees and friends of the Institute upon the possession of a corps of servants so zealous, industrious, and eminently qualified to teach the studies which it has hitherto been found necessary to establish. If we have charged inefficiency upon any branch, we must once and for all be understood to attribute the cause of it to the utter impossibility of effecting greater results under present circumstances. But those impeding circumstances are what we attack, and what we hope to remedy; and as the Faculty have merited your sincere thanks and gratitude in the past, we feel assured that they will equally merit them under any possible changes of conditions in the future.

RECAPITULATION.

Recommendations of the Committee.

1. That the standard of admission be raised.

2. A conference with the Board of Education as to the use of the Troy High School as a preparatory department.

3. Less of mathematics and more of technics in the mining engineering course.

4. A school of mechanical engineering.
   a.—Addition to an improved theoretical course, of the course referred to as "guides to the practical studies."
   b.—The appointment of a new professor.
   c.—Non-resident professors.
   d.—Working drawings and models.
5. That no considerable extension of the course in natural science be made.
6. A thorough course in Dana's Manual, with some practical extensions.
7. That sufficient time be allowed all the sections to carry out the study of chemistry in accordance with the programme.
8. * * *
9. * * *
10. That the mining and mechanical engineering courses discontinue spherical astronomy.
11. That special extensions of optics and acoustics be discontinued.
12. A rigid course in thermodynamics.
13. French text-books in some departments.
14. Lectures on electricity.
15. A professor of physics.
16. * * *
17. Literary exercises through the whole course.
18. Frequent literary exercises upon scientific subjects.

DEEP SEA EXPLORATION—HOW SOUNDINGS ARE OBTAINED.

From "The Student."

The first point to be determined in the exploration of what are often called the "fathomless abysses" of the ocean, is their actual depth. This, it might be supposed, would be very easily ascertained by letting down (as in ordinary sounding) a heavy weight attached to a line strong enough to draw it up again, until the weight touches the bottom; and then to measure the amount of line it has carried out. But this method is liable to very great error. Although a mass of lead or iron thrown freely into the water would continue to descend at an increasing rate (at least until the friction of its passage should neutralize the accelerating force of gravity), the case is quite altered when this mass is attached to the end of a rope, of which the immersed length increases as the weight descends. For the friction of the rope comes to be so great when a mile or more has been run out, as seriously to reduce the rate of descent of the weight, and at last almost to stop it; and as the rope will still continue to descend by its own gravity (which, when it is immersed, considerably exceeds that of water), any quantity of it may be drawn down, without the bottom being reached by the weight at its extremity. Further, if there should be any motion, however slow, in the water through which it passes, this current acting continuously against the extended surface presented by the rope, will carry it out into an almost horizontal loop, the length of which will depend upon the rate of the flow and the time during which the rope is exposed to it. Under such circumstances it is impossible that the impact of the weight upon the bottom, even if it should really reach it, can become perceptible above; and thus the quantity of rope which may have run out affords no indication of the actual depth of the sea-bed beneath the surface. Hence all those older soundings which were supposed to justify the statement that the bottom of the ocean is not less in some places than 6 or 8 miles from the surface, or may be even absolutely fathomless, are utterly unreliable; and no value can be attached to any of these that exceed a few hundred fathoms.

Various methods have been devised for obtaining more correct measurements; but it is not worth while to describe any, save such as have stood the test of experience; and there is now a general agreement as to the principle on which an efficient sounding apparatus should be constructed, although there are several different arrangements for giving to it practical effect. The principle is, that regard should be had in the first instance, not to recovering the plummet, or "sinker," which is a matter of quite subordinate consideration, but to securing the vertical direction of the line to which it is attached, so that the measurement of the amount run out may give as nearly as

possible the actual depth of the water through which the sinker has fallen.

The earliest mode of sounding on this principle was a very simple one. A cannon ball is attached to a reel of twine, of known length, made to turn very easily; the shot being let go, and allowed to descend as fast at it reels off, reaches the bottom with the least possible impediment; and a breaking strain then being put on the line, the depth is estimated by substracting from its entire length the portion still remaining on the reel. This method, however, has not been found to answer in practice. For if the line be not strong enough to allow of being put strongly on the stretch, it cannot communicate the shock of the impact of the cannon ball upon the sea bottom; and its want of tension renders it liable to be acted on both by gravity and by ocean currents, to such a degree that it continues to run out indefinitely, long after the sinker may be supposed to have reached the bottom. It is an additional objection to this method, that even if it could be worked in such a manner as to give true results, these data would be far from satisfactory; since we desire to know not merely the depth of the ocean bed at various points, but the nature of the bottom; in addition to which it has now become a matter of essential importance to ascertain the temperature of the bottom water; while it is also desirable to obtain a sample of that water, for determining the composition of the gases as well as of the solid matters which it holds in solution.

For the attainment of these objects, it is now found expedient to adapt the following plan: The sinker is connected, not with the line itself, but with an apparatus which is so constructed as to detach it when it touches the bottom; and the line is made sufficiently strong, not only to bear a considerable tension as the weight descends, but also to pull up the carrying apparatus, with any instruments attached to it, when the weight has been left below. The shock of its impact against the bottom, even at a depth of 3 miles, can then be distinctly recognized by a practised hand; and as a line of the required strength can be made small enough to run out very easily, its vertical direction can be pretty well secured, even at great depths, if the operation be carried on by an officer of ability and experience. For work of this kind, a steam vessel has a great advantage over a sailing vessel; since the former can be much more readily kept directly over the line of vertical descent, so as to obtain that true "up-and-down" sounding which is required for the correct estimation of the depth.

The nature of the bottom is ascertained in ordinary shallow water sounding by the examination of the small sample that may adhere to a lump of tallow introduced into a hollow at the bottom of the plummet. But for deep sea soundings it is desirable to employ some arrangement, whereby a larger sample may be brought up without any admixture of tallow; and for doing this, various contrivances have been devised. When the depth does not exceed 1,000 fathoms, so as to permit the use of an ordinary cylindrical deep-sea lead, weighing 100 lbs., which can be pulled up again by the line, nothing is more simple and effective than a conical cup attached beneath this, having a circular lid so fitted as to fall down and close it when an upward movement is given to the lead. For if the cup should penetrate into sand or mud, it fills itself with this before the lid falls down; while subsequent closure of its mouth prevents its contents from being washed out, while the lead is rising to the surface.

During the sounding voyage of the Bulldog, an apparatus was devised by Dr. Wallich, which, as having been subsequently much employed by Swedish explorers of the deep sea, merits special notice. This is constructed somewhat on the plan of a bullet mould; two hemispherical cups, which are kept apart while the apparatus is descending, being brought together by a spring which comes into action when the sinker detaches itself on reaching the bottom, so that a sample of the mud or sand into which they may have penetrated is inclosed between them. This "Bulldogmaskinen," as it was termed by Prof. Sars, has been very effectively used for obtaining, not merely samples of any deposit covering the sea bed, but also specimens of the animal life which it may support. It is obvious, however, that the information it can afford in regard to the latter must be very limited in comparison with that obtained by the use of the dredge; since the forceps can only inclose what happens to lie between them at the spot which they strike.

The sounding instrument now preferred in the British service is known as the "Hydra" apparatus; having been devised by Capt. Shortland, of her Majesty's surveying ship Hydra. It consists of a strong tubular rod, furnished with valves that open upwards, so as to allow the water to stream through it freely in its descent, while the mud or sand into which the tube is forced on reaching the bottom, is prevented by their closure from escaping This is loaded with sinkers; which are masses of iron, each weighing 100 lbs., having the shape of a cheese, with a perforation in the middle for the passage of the rod. One, two, or three of these sinkers may be hung upon it, in such a manner as to rest securely on their support while the apparatus is descending, but to fall off as soon as the rod strikes.

In the recent Porcupine expedition, the 100 lbs. deep sea lead, with a conical cup, was employed for sounding, when the depth was not supposed to exceed 1,000 fathoms. For soundings between 1,000 and 1,500 fathoms, the Hydra apparatus with 2 sinkers was employed; and for depths greater than 1,500 fathoms, 3 sinkers were used. The line to which these were attached was specially made for the purpose, of the best Italian hemp; and although not thicker than an ordinary lead pencil, it bears a strain of 1,200 lbs. It was allowed to run out as fast as the weight would carry it down, a moderate strain being kept upon it; and was reeled in by the donkey-engine provided for working the dredge.

The following particulars of the deepest sounding taken in the expedition will be interesting; since, though not the deepest on record, it is one of the deepest yet made which is thoroughly reliable, having been taken with the most perfect appliances, and managed by an officer of the greatest skill and experience, to whose practised hand the shock of the arrest of the weight at the bottom was distinctly perceptible, though this took place at a depth of nearly 3 miles.

The whole time occupied in the descent was 33 min. 35 sec.; and the rate at the end was about ⅓ of the rate at the commencement, the retardation being on the whole very regular. The reeling-in, which required great caution in order to avoid putting an undue strain on the line, its friction resistance being much greater than the weight it carried, occupied 2 hrs. 2 min. The pressure exerted by the water of the ocean upon whatever is submerged in its abysses, may be readily calculated when the depth is known. The weight of a column of sea-water, 1 in. sq., is almost exactly a ton for every 800 fathoms of its height; and consequently the pressure upon the bottom at 2,435 fathoms depth is rather over 3 tons upon every sq. in. This, however, has but very little effect upon the density of the water; for the compressibility of water is so slight that even the pressure just mentioned would certainly not reduce it by $\frac{1}{40}$ of its volume, or produce an increase in its density equalling the difference between salt and fresh water. The popular notion therefore, that a mass of iron or lead, thrown into the sea would encounter so rapid an increase in density of the water through which it sinks, that the deeper strata of the liquid would equal, or even exceed, the metal in density, and would thus hold it in suspension or even buoy it up, is altogether unfounded.

Fathoms.	Time.		Fathoms.	Time.	
	Min.	Sec.			
100	0	45	1,300	1	23
200	0	40	1,400	1	32
300	0	45	1,500	1	32
400	0	55	1,600	1	33
500	0	50	1,700	1	37
600	1	00	1,800	1	47
700	1	09	1,900	1	47
800	0	59	2,000	1	47
900	1	22	2,100	1	49
1,000	1	15	2,200	1	55
1,100	1	21	2,300	1	59
1,200	1	21	2,435	1	92

Not less unfounded are the statements that have been put forward upon professedly scientific authority, as to the effects which such pressure must exert upon any substances, whether mineral or organic, that may be exposed to it. Thus it has been asserted in an "Advanced Text-Book of Geology," that "at great depths, sand, mud, and all loose *débris* will be compressed and consolidated;" as if these substances were being squeezed in a Brahmah press, which should force out all their liquid, and bring their solid particles into the closest possible contact. The fact, now ascertained beyond all doubt, that sand or mud retains its ordinary condition at a depth of nearly 3 miles, under a pressure

of more than 3 tons on the sq. in., is perfectly accordant with the law of fluid pressure; for as such pressure acts equally in all directions, it will be exerted just as much in forcing in water between the solid particles as it is in pressing these particles together; and thus an equilibrium being uniformly maintained, the loose sand or mud of shallow water would remain absolutely unchanged in its condition, to whatever depth the bottom might subside. The same principle will be hereafter shown to apply to the case of animals whose bodies are composed of solids and liquids alone; such animals being able to "live, and move, and have their being" under the enormous pressure just mentioned, in virtue of its uniformity of distribution. The case is quite different, however, in regard to substances containing air; for this, under great pressure will either be forced out, or be reduced to extremely small proportional dimensions, its place being taken by liquid.

Thus it has happened that a boat having been dragged down by a whale to great depths, the wood of which it was made sank in the water like a stone, and this, not only when it was first recovered from the sea, but for a long time afterwards. And in like manner, not only the bodies of air-breathing animals, but those of fish provided with swimming bladders, would undergo great changes in size and form when submerged to great depths, owing to the extreme reduction in the bulk of their cavities.

ON ARTIFICIAL STONE AND VARIOUS KINDS OF SILICA.*

By The REV. H. HIGHTON, M.A.

From "The Building News."

Silica is found in various forms more or less soluble. Some kinds can only be united with akalies in the heat of a glass furnace; other kinds can be dissolved under a high pressure and after a considerable lapse of time by solutions of alkalies; other forms, again, to which the author particularly wished to call attention, can be dissolved under proper precautions, even in the cold. Natural silica of this kind was exhibited both from Germany and England. By means of this soluble silica artificial stone can be formed harder than any natural stone except the very hard granites and primitive rocks. The process is as follows:—

A concrete is made with any good hydraulic cement. When this is dry it is steeped in an alkaline solution of silica, in which is placed a quantity of free silica. The following chemical process then takes place:—The lime in the concrete extracts the silica from the solution, leaving the alkali free, which immediately attacks the free silica and conveys it in its turn to the concrete. This process goes on continually till the lime in the concrete is saturated with silica. By this process, within a week the strength of the concrete is increased from 50 to 150 per cent., and by a longer continuation of the steeping the strength is still more increased.

As the alkali acts only as a carrier of the silica, it is used over and over again; and it is in this that the economy of the manufacture consists.

The following is the comparative resistance to a crushing force of several kinds of stone:—

	Per. sq. inch. lb.
The Silicated Concrete or Patent Victoria Stone	6441
Aberdeen Granite	7770
Dartmoor Granite	6993
Peterhead Granite	6216
Yorkshire Landing	5851
Stafford Blue Brick	4032
Portland Stone	2426
Bath Stone	1244

The stone formed in this manner has been tried as a pavement in the busiest part of Cheapside, and in many other parts of London, and for steps, lintels, sills, etc., in many parts both of this kingdom and abroad, as well as in India.

The whole of the stone in the new warehouses, 27 S. Mary Axe, is made in this manner.

As a cheap, strong stone, when manufactured on a large scale. it is likely to

* Abstract from a paper read before the British Association, Liverpool Meeting, Section B.

supersede natural stone, except where the latter is very cheap and abundant.

In localities, as on the Thames, where there are facilities for obtaining good hydraulic cement and hard broken stone, it can be manufactured at a much lower cost than Yorkshire or other stone can be procured.

COMPRESSION AND TRANSMISSION OF AIR THROUGH LONG PIPES.

Mr. Horace H. Day, of Bloomingdale, N. J., proposes to utilize the waste power of natural waterfalls by employing it in the compression of air, and forcing it through tubes of such length as may be required to reach the engine or motor by which power is to be applied.

Mr. Day has conceived the bold plan of thus employing a small fraction of the enormous store of power at Niagara, and transmitting to Buffalo, 20 miles distant, for the use of manufacturers.

The preliminary experiments by which it was sought to determine the feasibility of such a plan were tried lately at Bloomingdale by Mr. Wm. S. Henson, C. E., of Newark.

The following is Mr. Henson's report:

MR. HORACE H. DAY: DEAR SIR,—In accordance with your request, I submit to you the result of my observations of your experiments at Bloomingdale, in the compression and transmission of air through pipes as a means of utilizing power at long distances from its source. In order to carry out your demonstrations and experiments, you have laid 2 miles of pipe; that is, two separate and distinct pipes of 1 mile each, both of lead, and 1¼ inches diameter (inside measure); 1 mile reaches from a mill situated about ¾ of a mile off, and in its course passes over the side of a mountain, which I rightly estimated at about 300 ft. high, and over very rough, uneven ground, the mile being completed by passing partly round a field adjoining your place, and then terminating in your mill. The other mile of pipe starts from your mill, passes twice round your premises and an adjoining field, and then runs about 500 ft. along one side the field and back again to complete the mile, terminating at your mill. Both pipes run over very rough, uneven ground, and are full of crooks, bends and angles—the weight of the pipes having caused them to assume the profile of the ground. There is an air-compressor and a receiver for each pipe; each air-compressor consists of a horizontal cylinder, 5 in. diameter, and provided with suitable valves at each end, and a piston driven by a crank and pulley, like a common, double-acting steam engine reversed and used as a double-acting pump; each receiver consists of a cylinder 30 ft. long and 16 in. diameter, made of boiler-plate and strongly riveted. One compressor and receiver is located at the mill, ¾ of a mile away, and is driven by the water-wheel there; the other compressor and receiver are situated upon your own premises, and the compressor is driven by a small turbine wheel, of about 2½ horse power. Each compressor pumps the compressed air directly into its own receiver, situated near it, whence it flows into the connecting pipes, which both terminate at your place, where there is an excellent vertical cut-off steam engine of A. K. Ryder's patent, having an 8″ cylinder, 10″ stroke, estimated at 17-horse power, built by the Albany Street Iron Works, New York. The cut-off is admirable for its simplicity and effectiveness, and the design and workmanship of the engine reflects great credit upon the constructors. The pipes are so arranged in connection with this engine, that it can be driven by either compressor alone, or both connected, or the air from the compressor, situated ¾ of a mile off, can be sent through the 2 miles of pipe in succession.

The theoretical power required to drive one of these compressors 100 revolutions per minute, when compressing to 75 lbs. above the atmosphere, or 6 atmospheres altogether, is estimated at 5.87-horse power, plus the friction. This calculation is based on the well-known law of Mariotte, viz.: that with equal temperatures the pressure is inversely as the volume, as although there is generally a considerable increase of temperature in the act of compressing air, yet with good compressors this heat can be so nearly all ab-

sorbed that Mariotte's law will practically hold true.

In 1837 a series of experiments were made by order of the Italian Government (preliminary to the commencement of the Mont Cenis tunnel) on the resistance of tubes to the flow of air through them, one of the principal objects being to ascertain the laws which govern the variations of resistance, when the velocities of flow and the diameters of tubes are varied, as well as to determine the practicability of using compressed air in driving the tunnel. From the results of these experiments the 3 following laws were deduced, as reported by Professor Barnard (see his able report on the Paris Universal Exposition for 1867, republished by Van Nostrand, New York):

1st. "The resistance is directly as the length of the tube;"

2d. "It is directly as the square of the velocity of flow;"

3d. "It is inversely as the diameter of the tube;"

and your experiments, as far as they have gone, have confirmed the substantial truth of the first and third propositions, and demonstrated the existence of another law of vast importance to the practical transmission and application of the power of compressed air through pipes for long distances, viz.: that the loss per cent. of the whole power from friction in transmitting a given mass, or, more properly speaking, weight of air, through a pipe of given dimensions, diminishes inversely in a geometrical progression, the divisor or ratio being 2 for every increase of 10 lbs. pressure, as may be seen by inspection of the fol owing table, obtained from actual experiment. The pressure gauges used in these experiments are the same kind as those ordinarily used on steam engines, and made by E. H. Ashcroft, the dials being marked at every 5 lbs., and the intermediate divisions measured and read by the eye alone. The pipe used is one of the two mentioned above, one mile long and one and a quarter in. diameter, commencing and terminating on your premises; the air compressor being one situated on your place. The pressure gauges being located both in the same room, could be readily compared with each other, the first gauge being placed near the beginning of the mile of pipe, and the second gauge near the end of it; and the readings are as correct as I could measure them by the eye alone. The water power driving the compressor was so regulated as to deliver the same weight of air at each experiment, that is, 120 cylinders full per minute, 5 in. diameter, and 20 in. long.

The velocities are calculated from the volumes due to the pressures, according to Mariotte's law, and the pressure at the second gauge was obtained by partially closing a valve attached to the end of the pipe until the desired pressure was obtained; and at which both gauges remained constant, without further adjustment, some 15 or 20 minutes. The second table below was obtained from the first by calculation up to 100 lbs.

Number of strokes of Compressor per minute.	1st Gauge Pressure, in pounds.	2d Gauge Pressure, in pounds.	Velocity at beginning of pipe, in feet, per second.	Velocity at end of pipe, in feet, per second.	Mean velocity per second.	Loss from friction in pounds.	Loss per cent. of the whole power delivered by Compressor.	Percentage of loss calculated from last column.
120	22	10	21	32	26	12	54.50	54.50
120	28	20	18 06	22 6	20.6	8	28.57	27.25
120	35.25	30	16	17 8	16 9	5.25	14.89	13.67
120	43.25	40	13.66	14.33	13 99	3.25	7.51	6 83
120	51 75	50	12	12.26	13.13	1.75	3.38	3.41

SECOND TABLE.

	61.03	60		10.66		1.03		1.70
	70.596	70		9.38		.596		.852
	80.341	80		8.46		.341		.426
	80 192	90		7.62		.192		.213
	100.100	100		6.93		.100		.106

It will be observed that if the percentage of loss in the eighth column, commencing at the top, is divided by 2, it will give 27.25 in the 9th column, 2d line, and that again divided by 2 gives 13.67; and if this process is continued in succession, it ends with 3.41 in place of 3.38, as got by experiment, and by continuing the same process the last column of the second table was obtained. It will be also observed that a very slight variation in the readings of the gauges would make the differences between the eighth and ninth columns in the first table.

These results, while demonstrating the necessity of a high degree of compression—say from 85 to 100 lbs. per in.—to reduce the loss resulting from transmission through long distances of pipe, are at the same time extremely favorable, as for transmitting great quantities of power the air requires to be considerably compressed, and both objects are thus gained by high compression.

These experiments, made alone by myself with great care, to discover the cause of observed variations, are entirely confirmed by reference to your records, extending through several months, and made before we were looking for, or were conscious of, any law on the subject.

In response to your request for the elements necessary for the transmission of 5,000-horse power from Niagara Falls to Buffalo (about 20 miles), using your magnificent power of 206 ft. fall, I suggest the utilization of 185 ft. of this fall by the direct compressing power of a column of water acting as a ram, without the intervention of water wheels or the friction of cylindrical compressors with moving pistons, because by the use at *that point* of such compressors, you absorb the heat generated in the act of compression, and avoid the loss from friction by piston or cylinder, and all the wear and tear of ponderous water wheels.

This direct acting hydraulic pressure, working in one sense as a ram, may be made to develop any amount of pressure desirable, and, taking into account the cost of pipes and other considerations, I would suggest that the pressure should not be less than 80 lbs. or more than 100 lbs. per square inch; and a pipe of 42 in. in diameter would transmit from Niagara Falls to Buffalo a column of air compressed to 100 lbs., with a velocity of 10 ft. per second, and a loss from friction of tube, for the whole distance, not exceeding 1 per cent. of the power transmitted, and deliver for us over 5,000-horse power of cold air. I should recommend, however, a pipe of 36 in. diameter, which should deliver a column of air at 100 lbs. pressure, and 14.33 ft. per second terminal velocity, and give a full 5,000-horse power of cold air, worked expansively, at a loss by friction not exceeding 5 per cent. for the 20 miles.

Great unnecessary loss would result if common non-expanding steam engines were to be used to work off the power; and the more perfect the compressors for condensing the air, and the greater the excellence of the steam engines, the better.

You propose to construct the pipe with boiler plate $\frac{1}{4}$ in. thick, and paint it both inside and out with a strong, indestructible varnish, whereby it will not only be rendered absolutely air-tight, but will be perfectly protected from corrosion.

Before closing my report, I will only refer to your experiments for expanding the compressed air, at the moment of its use, through the steam engine. As you are taking out patents for your discovery, I need only remark that, in my judgment, it will contribute in no small degree towards that growing appreciation everywhere manifested by the intelligent public for compressed air as a motive power.

Professor Charles S. Storrow, an eminent engineer of Massachusetts, and the commissioner employed by that State to proceed to Europe to examine the works there going on, and especially that for tunnelling the Alps, to discern the practicability of finishing the Hoosac Tunnel by compressed air, in the closing part of his report, introducing a minute description of the process practised at Mont Cenis, uses the following expressive language, which is so just and appropriate that I may be excused for quoting it here:

"For the construction of the tunnel, the great instrument in the hands of the engineer is compressed air—and what an instrument it is! By its aid they furnish air for respiration, wind to drive away vapors, power to run machines. They eject water to play against the rocks, produce cold to temper the atmosphere, and

heat by a blast of the forges near the entrances. Thus air, wind, power, water, cold, heat, can be applied, and precisely where they are wanted. This sounds like fable, but it is a literal truth."

W. S. HENSON.

THE MECHANICAL WORK OF WALKING.

Translated from Weisbach's "Ingenieur und Maschinen Mechanick." (Vol. 2.)

In walking on a horizontal path the whole body turns about the point of contact (C) of the advanced foot.

If h is the height (D E) through which the centre of gravity rises, l the length of the leg (C A, C B), s the length of the step (C H, C R), we have $DE = \frac{AD^2}{2AC}$, or $h = \frac{s^2}{8l}$. Let G = the weight of the man, Q = the weight of his burden; then the work

$$L=(G+Q)\,h=\frac{(G+Q)s^2}{8\,l}$$

and the force

$$P=\frac{L}{s}=\frac{(G+Q)s^2}{8\,l}$$

Suppose $l = 3$ ft. and $s = 2$ ft., then the force

$$P=\frac{2\,(G+Q)}{8.3}=\frac{1}{12}(G+Q)$$

If Q = 0 and G = 140 lbs.
$P=\frac{1}{12}G=11.67$ lbs.

Hence the work done in making a horizontal step, s, is equal to that done in rising vertically to a height $\frac{1}{12}s$; and the effort required is equal to that of lifting a weight of 11.67 lbs.

In walking up an inclined plane (Fig. 2) of inclination a, if β = the angle between successive positions of the leg, we find

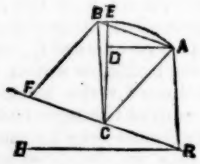
$$DE=h=CE-CD=CE\,(1-\text{Cos. A C D})=$$
$$l\left[1-\text{Cos.}\left(a+\frac{\beta}{2}\right)\right]=l\left(1-\text{Cos. }a\,\text{Cos.}\,\frac{\beta}{2}+\text{Sin }a\,\text{Sin}\,\frac{\beta}{2}\right)$$

and approximately, for a small stepping angle a,

$$h=l\left(1-\text{Cos}\,\frac{\beta}{2}\,\text{Sin }a\,\text{Sin}\,\frac{\beta}{2}\right)$$
$$=l\left(\frac{s^2}{8\,l^2}+\frac{s}{2\,l}\,\text{Sin }a\right)=\frac{s}{2}\left(\frac{s}{4\,l}+\text{Sin}\,a\right)$$

The mechanical work of each step:

$$L=(G+Q)\,h=(G+Q)\left(\frac{s}{4\,l}+\text{Sin }a\right)\frac{s}{2}$$



The mean force:

$$P=\frac{1}{2}(G+Q)\left(\frac{s}{4\,l}+\text{Sin}\,a\right)$$

In walking down hill a is negative, and

$$P=\frac{1}{2}(G+Q)\left(\frac{s}{4\,l}-\text{Sin}\,a\right).$$

In this case if $\text{Sin}\,a=\frac{s}{4\,l}$, the work is zero.

If $l = 3$ and $s = 2$, we have
$\text{Sin}\,a = 1\frac{1}{8} = 0.1666$.
$\therefore a = 9\frac{1}{2}°$, the angle of easiest descent.

If $a=\frac{\beta}{2}$ the work of walking up is

$$P=\frac{(G+Q)s}{4\,l},$$

and $a>\frac{\beta}{2}$ i. e. $>\frac{s}{2l}=\frac{1}{6}$;

that is, if $a > 19°$, we have

$$P=(G+Q)\,\text{Sin}\,a.$$

ON THE EXPLOSIVE ENERGY OF HEATED LIQUIDS.

By W. J. MACQUORN RANKINE, C.E., LL.D., F.R.SS. L. AND E.

From "The Engineer."

1. *References to Theoretical Investigations.*—In contemplation of the revival of the application (first invented by Perkins) of the sudden evaporation of highly heated liquid water, in order to propel projectiles, it may be useful to give a summary of the rules for calculating the utmost theoretical effect of a given fluid when so employed, under given circumstances. For the theoretical deduction of those rules from the laws of thermodynamics I have to refer to two independent investigations, made respectively by myself and by Clausius; the former published in the "Philosophical Transactions" for 1854, pages 160 to 162; the latter in "Poggendorff's Annalen" for 1856. The rules themselves, with some tables of their results, having reference to the bursting of steam-boilers, have also been published in the "Transactions of the Institution of Engineers in Scotland" for 1863-4, vol. vii., page 8; and in the "Philosophical Magazine" for 1863, vol. xxvi., pages 338 and 436. In a subsequent communication I propose to consider the case when the fluid passes into the state of vapor before its admission into the gun.

2. *General Formulæ for all Fluids.*—Suppose a closed boiler to be entirely filled with a fluid in the liquid state at a certain absolute temperature t_1. Let the absolute temperature t_2, being lower than t_1, be the boiling point of that fluid in a boiler open to the atmosphere. Let a given mass of the liquid be made to escape from the boiler, and to perform work by expanding partly or wholly, as the case may be, into the state of vapor, and driving a solid body (such as a bullet) before it, until its pressure falls to that of the surrounding atmosphere, and its absolute temperature (consequently) to t_2. Then the energy exerted by that mass of fluid is equivalent to the raising of its own weight to the height given by the following equation:—

$$U = K t_2 (n - 1 - \text{hyp. log. } n) \quad . \quad . \quad (1)$$

in which K denotes the dynamical value of the specific heat of the fluid in the liquid state; and $n = \frac{t_1}{t_2}$ the ratio in which the initial absolute temperature is greater than the final. Moreover, the following formula gives the excess of the space filled by each unit of weight of the fluid at the end of the expansion, above the space filled by an unit of weight of the liquid:

$$s = \frac{K \text{ hyp. log. } n}{\frac{dp_2}{dt_2}} \quad . \quad . \quad . \quad . \quad (2)$$

in which $\frac{dp_2}{dt_2}$ denotes the rate at which the pressure of saturation varies with the boiling point, at the final temperature.

Absolute temperatures are given, as is well known, by adding 461.2 deg. to temperatures on the ordinary Fahrenheit's scale, or 274 deg. to temperature on the ordinary Centigrade scale.

3. *Formulæ for Water.*—For water the values of the co-efficients in the formulæ are as follows very nearly:

$$K t_2 = 520{,}000 \text{ ft.};^*$$

$$\frac{K}{\frac{dp_2}{dt_2}} = 18.38 \text{ cubic feet per lb.};^\dagger$$

or to a rough approximation about 1,100 times the volume of the hot liquid water. Hence we have the following formulæ for water; energy of the explosion in foot pounds per pound of water:

$$U = 520{,}000 \ (n - 1 - \text{hyp. log. } n) \quad . \quad . \quad (1A)$$

Space swept by the explosion, or final volume of the water and steam in cubic feet to the pound.

$$s = 18.38 \text{ hyp. log. } n \quad . \quad . \quad . \quad . \quad (2A)$$

or in terms of the volume of the liquid water,

$$1100 \text{ hyp. log. } n, \text{ nearly}, \quad . \quad . \quad . \quad (2B)$$

4. *Examples.*—To illustrate the results of the preceding formulæ, the two following examples are given, in which the values assumed for n are respectively 2 and $2\frac{1}{4}$. The pressures corresponding to the temperatures given by those ratios are not known by experiment. The pressures given in the following table of results are calculated on the assumption that the formulæ which are found to be accurate up to the limits of experiment, are applicable

* 158,500 metres, nearly.

† 1.147 cubic metres per kilogramme, nearly.

also to temperatures far beyond those limits; hence, those pressures are to be viewed as in a great measure conjectural. This affects the safety of the boiler and of the gun; but not the energy of the explosion, nor the final volume of the fluid; for these two quantities vary with the temperature only.

	Example I.	Example II.
Ratio of initial to final absolute temperature	2 ..	2¼
Final absolute temperature, Fahr.	673 2° ..	673.2°
Final absolute temperature, Cent.	374° ..	374°
Initial absolute temperature, Fahr.	1346.4° ..	1514.7°
Initial absolute temperature, Cent.	748° ..	841.5°
Initial temperature, ordinary scale, Fahr.	885.2° ..	1053.5°
Initial temperature, ordinary scale, Cent.	474° ..	567.5°
Energy of the explosion, foot pounds per pound of water	159,562 ..	228,189
Final volume—cubic feet per pound of water and steam	12.74 ..	14.9
Final volume—ratio to initial volume of water, nearly	760 ..	890
Conjectural absolute pressure in boiler, pounds on the square inch	7,180 ..	13,345
Ditto, ditto, in atmosphere	490 ..	908

The values of the energy of the explosion in the two examples agree very nearly with the least and greatest values found by experiment for the energy of the explosion of 1 lb. of gunpowder; hence the examples may be taken as showing the conditions which must be fulfilled in order that 1 lb. of heated water may produce the same effect as 1 lb. of gunpowder. In both examples the initial pressures are so high that the only safe form of boiler is a coil of tube of small bore compared with its thickness. This was the form employed by Perkins.

5. *Expenditure of Heat.*—The expenditure of heat required in order to produce the elevation of temperature of each unit of mass of liquid from the temperature of the feed to that at which it escapes from the boiler, is expressed in dynamical units as follows:

$$H = K (t_1 - t_2) \quad . \quad . \quad . \quad . \quad . \quad (3)$$

in which t_2 denotes the absolute temperature of the feed. Let this latter temperature bear the ratio n^1 to the absolute temperature of the atmospheric boiling point; then we may express the same expenditure of heat in the following manner:

$$H = K t_2 (n - n^1) \quad . \quad . \quad . \quad . \quad (3A)$$

and for water, the value of this in foot pounds per pound, is very nearly

$$H = 520{,}000 (n - n^1) \quad . \quad . \quad . \quad (3B)$$

The value of n^1 for water ranges in ordinary cases between 0.7 and 0.8. Assuming it to be 0.75, the expenditure of heat in the two preceding examples is found to have the values given in the following table:

Heat expended.	Example I.	Example II.
Foot pounds per pound	650,000	780,000
Units of evaporation	0.873	1.047

The difference between the quantities in the first line and the values of the energy of explosion, are the quantities of heat which go to waste with the escaping steam and water after the explosion, viz.:

Waste heat.	Example I.	Example
Foot pounds per pound	430,138	551,811

6. *Efficiency of the Explosion.*—This term may be used to express the ratio borne by the energy of the explosion to the whole expenditure of heat. Its value is as follows:

$$\frac{U}{H} = \frac{n - 1 - \text{hyp. log. } n}{n - n^1} \quad . \quad . \quad . \quad . \quad (4)$$

And it is to be observed that this value depends solely on the ratios borne to the absolute temperature of the atmospheric boiling-point, by two other absolute temperatures, viz., that of the feed water, and that of the liquid just before it escapes from the boiler. In the two examples the values of the efficiency of the explosion are respectively;

Example I.	Example II.
0 245	0 293

7. *Remarks.*—The preceding formulæ all proceed on the assumption that the specific heat of the liquid is sensibly constant. This is not perfectly accurate, for the specific heat of every liquid increases slowly with the temperature. The effects of that increase are shown in the original theoretical investigations referred to at the commencement; but for practical purposes it is unnecessary to take them into account.

The formulæ also take no account of the retarding effect of friction on the bullet, nor of the inertia of the air which it drives before it in the barrel of the gun, nor of the loss of energy which may take place through the abstraction of heat from the water by the metal of the barrel; those being quantities which can be determined by direct experiment alone.

The initial temperatures assumed in the examples have been chosen so as to make the explosive energy of the water nearly equivalent to that of an equal weight of gunpowder. By choosing a lower initial temperature the initial pressure may be moderated; but the explosive energy of a

given weight is at the same time diminished; and a greater mass of water must be used in order to obtain a given amount of energy, thus increasing the proportionate quantity of energy which is lost in propelling the explosive material itself, as the following section will show:

8.—*Efficiency of Projection.*—This term may be used to denote the proportion which the energy of the bullet at the instant of its leaving the gun bears to the whole energy of the explosion.

Let m denote the ratio which the mass of the bullet bears to the mass of the explosive material; M the ratio which the whole mass that recoils bears to the mass of the explosive material; v the velocity of the bullet at the instant when the action of the explosion ceases, so that the energy of the bullet at that instant, *per unit of mass of explosive material*, is $\frac{m v^2}{2g}$; then, neglecting fraction and the inertia of the air, etc., it can be shown that the energy of the explosion of an unit of mass of explosive material is disposed of in the following manner:

$$U = \frac{v^2}{2g}\left\{ m + M\left(\frac{2m+1}{2M+1}\right)^2 + \frac{1}{2}\left(1 - \frac{2m+1}{2M+1} + \left(\frac{2m+1}{2M+1}\right)^2\right)\right\} \quad . \quad (5)$$

On the right-hand side of this equation the first term $\frac{m v}{2g}$ is the energy of the bullet.

The second,

$$\frac{M v_2}{2g}\left(\frac{2m+1}{2M+1}\right)^2$$

is the energy of the mass which recoils.

And the third,

$$\frac{v_2}{6g}\left(1 - \frac{2m+1}{2M+1} + \left(\frac{2m+1}{2M+1}\right)^2\right)$$

is the energy of the projectile motion of the products of explosion, at the instant when they cease to act on the bullet. Hence the *counter-efficiency* of projection, being the reciprocal of the efficiency, or in other words, the ratio in which the whole energy of the explosion is greater than that of the bullet, is expressed as follows:

$$c = 1 + \frac{M}{m}\left(\frac{2m+1}{2M+1}\right)^2 + \frac{1}{3m}\left\{1 - \frac{2m+1}{2M+1} + \left(\frac{2m+1}{2M+1}\right)^2\right\} \quad . \quad (6)$$

from which it appears that the energy lost through the projection of the products of explosion is greater, the greater the proportion $\frac{1}{m}$ borne by the mass of the explosive material to that of the bullet, and that when the proportionate weight M of the recoiling mass is very great, that lost energy is approximately equal to the fraction $\frac{1}{3m}$ of the energy of the bullet.

For example, let $m = 8$, and $M = 1000$; then the three terms of the counter-efficiency of projection have the values shown in the following equation to three places of decimals: $c = 1 + 0.009 + 0.041 = 1.050$; that is to say, the energy lost in the recoil is 0.009, and the energy lost in projecting the products of explosion 0.041, of the energy of the bullet; the latter being by far the more important loss; and hence it is desirable not to increase unnecessarily the comparative weight of the explosive material.

FRENCH ENGINEERING BEFORE THE WAR.

From "The Builder."

The science and the practice of the engineer are receiving daily illustration in the course of the present war. The scientific corps of the army have attained an importance which is not undue, but which is certainly unprecedented. Even that great engineer, captain, and legislator, who commenced his career as a lieutenant of artillery in the regiment of La Fère, never contemplated the dominant importance which his favorite arm was to assume in the combinations of the strategist. Everywhere we see the same lesson. In the field the victory remains to the best ordered and best handled artillery. Courage and even tactical genius count for nothing before superior batteries. The tide of war spreads round the great railway lines, overflowing its banks, like the Nile, but still fed by the steady main stream of communication. The relation between the number of days that a fortress can hold out, and the number and calibre of the siege guns, is becoming

more clearly than ever a matter of elementary arithmetic. The opinion laid down by no less eminent an authority than Julius Cæsar, that Fortune tells for much in war, must now be checked and modified by the axiom that Science tells for more.

While the progress of war thus taxes the utmost efforts of human skill, it, in some instances, ruthlessly destroys the noblest public works. At a time when so many of the engineering monuments of France are in danger of being swept away, it is unusually instructive to glance at some of the latest triumphs attained by the civil engineers in that country.

In regarding the historic progress of mechanical skill, it is natural to consider that the most simple inventions are those which we owe to the infancy of science. Moreover, complexity, accompanied, it may be, by striking elegance of arrangement, and giving evidence of patient and exhaustive thought, characterizes the greater part of modern improvements in mechanism. But for the primary application of science to practice we must, for the most part, cast our glances back to a period when the human mind, if less full of knowledge than at present, evinced a more perfect mastery over the elements at its command. For the origin of the pendulum, indeed, we can only look back for a comparatively short period of time. But the invention of the pendulum closely accompanied the first sound investigation of the laws of falling bodies. In the same way the invention of the barometer, and the complete mastery of the theory of the pump, accompanied the discovery of the pressure of the atmosphere. A method of raising water, yet more simple than the pump, is associated with the name of Archimedes; and there is no reason to doubt that the problem of the reflection of light, and the concentration of radiant beams, was practically solved by that great philosopher.

With regard to some of the simple utensils of human art, their origin is lost in obscurity. Some tradition of the earliest use of fire is preserved in the legend of Prometheus; but the form is not such as to make the information which it hides readily intelligible to ourselves. Ancient Semitic history is silent on this grand question; although it refers to the discovery of wine. Among the tools familiar to our hands, while the circular saw is barely a century old, and the ribbon saw not a tenth of that age, the saw itself is of immemorial antiquity. It may be considered that, like the knife, the axe, the arrow-head, and the wedge, it represents a natural subdivision of that series of original sharp flint cutting instruments which we know to have preceded the use of metallic tools. The scissors and the shears, on the contrary, must have been invented after metallurgy had made some advance, and probably after the discovery of iron. The invention of the bellows is probably coeval with that of the forging of metal, and must have preceded any successful attempt at smelting, except in the rudest manner, and from the richest ore. It is not generally known that the wandering tinkers of Italy—men who bear the traces of gipsy blood—make use of a form of bellows entirely different from that common to the Northern European nations. The gipsy bellows consists of a pair of bags of skin, which are closed by 2 straight pieces of wood. A loop on each of these bars serves for the insertion of the thumb and finger. A wind bag is worked alternately by each hand; the arm being lifted, and the finger and thumb opened, to admit the air, and then the finger and thumb being brought together, the slit is closed, the arm depressed, and the air is thus forced through a pipe into the fire, now on the right, now on the left of the blower; who squats on the ground between these primitive implements. The "blast and counter blast" of the smith's forge, referred to by the oracle of Amphiaraus as to the discovery of the grave of Orestes, is far more appropriately referrible to this Italic form of bellows than to our Teutonic valved chamber.

If the present inventions from which all mechanical improvements have sprung are for the most part so ancient and so fruitful, no ordinary degree of merit must attach to any modern discovery which can apply, for the first time in human history, a well-known principle to a well-known want which it is fully competent to supply. A practical step of this nature has been taken by M. Beau de Moulin, an engineer-in-chief of the French Corps of Engineers of Ponts et Chaussées; and we consider it to be one demanding the most serious attention, and deserving the widest fame.

Every engineer and every architect who has had the responsibility of building a large bridge, is aware of the anxiety attendant on the easing and striking of the centres. The need of providing firm reliable points of support on which great weight may be safely brought, but which may be readily movable at will, is not confined to bridge building. Among the many cases in which it is desirable to resist such a power at command may be mentioned the launching of vessels, and, generally, the dealing with enormous weight. The tendency of our recent practice, in this respect, has been in favor of the use of hydraulic power. This, however, is both costly and cumbrous, and requires an amount of previous preparation which consumes much time, and has interfered with the application of a method, the power obtained by which is no secret.

M. Beau de Moulin has availed himself of one of the well-known properties of sand—of that mechanical fluidity of its particles, with which we are all familiar in the hour-glass. So simple and so beautiful is the application, that one hears of it for the first time with a positive blush of shame that it should have been left to our own time undiscovered.

The method to which we refer is the simple and beautiful plan of throwing the bearings of the ribs of a centre upon sand, contained in iron cylinders, from which it is allowed slowly to escape at will.

Each principal is supported upon round props, fitting as pistons into cylinders filled with fine dry sand. These cylinders are of sheet iron, $\frac{1}{32}$ in. thick, 1 ft. high, and 1 ft. in diameter. At 2 in. from the bottom each cylinder is perforated with $\frac{3}{4}$ in. holes, which are stopped by common corks. To ease the centring it is only necessary to remove the corks. The sand immediately flows from each hole, forming a cone outside the cylinder. The formation of this cone arrests the further escape of the sand, and therefore stops the gradual descent of the piston which follows on the escape. As the sand is swept away, the issue recommences, and may be thus continued, or arrested, at will, till the centring is entirely detached from the masonry. By carefully regulating the issue from the holes, the utmost delicacy of movement may be imparted to the centre. It may be eased at the same moment in each part, or either end of any principal may be made to descend with greater or less rapidity. The inventor, indeed, claims the power of graduating movement by millionths of an inch; and it is not easy to say what is the practical limit of delicacy attainable by the process. Not the slightest shock is caused by a mode of operation which appears to be not only theoretically but practically perfect. The idea would have done honor to the most illustrious name in the history of human science.

The use of this admirable method of replacing the maul of the carpenter, and the wedges of our early bridge builders, was tested on an arch of very unusual proportions. It was desired to construct a bridge over the Seine, in Paris, to connect the Rue du Louvre with the Rue de Rennes. The bridge had to span one of the locks of the Canal de la Monnaie. The springing of the arch, therefore, had to be clear of the canal walls, while the crown was kept down by the necessity of preserving the level of the roadway. The rise of the arch, thus determined, was about $\frac{1}{18}$ of its span, or 6 ft. 11 in. in 124 ft.

The architectural harmony of the situation demanded that the new bridge should be constructed of stone. With a wise perception of the fact that it would not do to risk experiments in the midst of Paris, M. Vaudray, the engineer, took the precaution of building an experimental arch, before venturing to throw such an unprecedented piece of masonry over the Canal de la Monnaie.

The spot selected for the experiment was the quarry of the plains at Soupes, 60 miles from Paris, on the Bourbonnais Railway. One abutment was formed by the natural face of the rock, the other by a block of masonry, 27 ft. high, 49 ft. deep, and of the same width as the arch, viz., 12 ft. It was built of rubble masonry, well bonded, and laid in Portland cement mortar, one part of cement to three parts of sand. Its construction occupied 20 days. The arch itself was built of 77 voussoirs of cut stone, the depth of the key-stone being 2 ft. 8 in., and the ring gradually increasing in depth to 3 ft. 7 in. at the springing. The beds and joints were carefully dressed and laid in Portland cement mortar, two parts of sand to one of cement. The thickness allowed to each

joint was $\frac{3}{8}$ in. The joints next the skew-back were not flushed until after the completion of the ring, having been kept open by means of fir wedges.

The arch was allowed to rest for four months on the centring, which was then eased by allowing the sand to escape from the cylinders. The effect which was produced by the slackening of the centres was watched with the utmost attention. In an hour daylight was perceptible between the soffit of the key-stone and the lagging. In two hours the centring had entirely left the arch. It was then found that the crown had come down 6-10ths of an inch, and that the joints of the skew-back on the built abutment side had opened 7-100ths of an inch. After the lapse of three days the arch was observed to have sunk 7-100ths of an inch more. It was then loaded with a weight of 360 tons, disposed over the whole surface of the roadway, an operation which occupied 13 days. The crown was brought down by the weight 3-10ths of an inch more.

Since that time nothing has stirred. The arch has been tested by allowing a weight of 5 tons to fall upon the roadway from a height of 18 in., without causing the slightest injury to the bridge. The triumphant execution of a masonry arch of such unprecedented proportions is a credit to French science and practice. It is unnecessary to insist on the accuracy of workmanship that is requisite for such a structure, or to point out how much the engineer was indebted to the method employed for striking the centres of his arch.

Reports on the great French engineering works have been published under the auspices of the Minister of Agriculture, Commerce, and Public Works. It is to be feared that we have seen the last of these reports that will be issued for a considerable time. An unrivalled collection of models, plans, and specifications, explanatory of bridges, viaducts, reservoirs, docks, and tunnels, illustrates the state and progress of civil engineering in France. It is much to be desired that so good an example should be followed in our own country. The records of our great public works, and the detailed information gained during their progress, should not be left to the enterprise of publishers, or even to the paternal vanity of engineers. The recent public works of London alone, including the Thames Embankment, the main drainage, the river bridges, the metropolitan railways and termini, are such as to entitle Great Britain to an eminent position among engineering nations, and should be recorded with such literary and graphic luxury as befits their historic importance.

The chief works of the Old World during the present quarter of a century are the tunnel under Mont Cenis, and the canal through the Isthmus of Suez. Both these important works owe their origin, if not their entire conduct, to French enterprise. It would be unworthy of the profession of the civil engineer, as carried out in this country, to entertain either jealousy or regret at the great progress which our professional brethren on the Continent have made since the date of the introduction of the railway system into France. Yet it is well that it should be borne in mind how much of this actual advance is due to the impulse, not only intellectual, but financial, of this country. English engineers not only wrought out the railway system in this country, but introduced it on the Continent. Their experience and advice were eagerly sought, and not only so, but the financial support which their names were once accustomed to command, proved to be a *sine quâ non* for the start of many of these undertakings, which now form so important a part of the Continental system of communication. In France, indeed, we have been far more fairly dealt with than in other Continental countries. The highly educated and thoroughly organized corps of the engineers of the *Ponts et Chaussées* lost no opportunity of acquainting themselves thoroughly with the best results of our English expenditure. What the civil and mechanical engineers of France have accomplished during the last 15 years would seem incredible to those who are not practically acquainted with the subject. In the manufacture of iron, the most decided progress has been made. The rails which were supplied from the French *usines* for the Chemin de Fer du Midi were of such a quality that they often snapped beneath the mere weight of the ponderous locomotives that a French house was then beginning to supply. A fitter, with a hammer and a cold chisel, could cut through any one of these

rails, with ease, in twenty minutes—that is to say, an English fitter. And so difficult proved the task of supplying even these inferior rails in adequate quantity, that a number of miles across the Landes of Bordeaux, for which the French factories were under contract to supply the rails, were actually laid with Barlow's rails, sent out from this country, to the great economy of time and increase in durability of way, no less than of safety to the public.

How thoroughly this state of things has been changed it is unnecessary to say. In fact the only part of the case that now would be thought incredible is the statement of what formerly existed. In other parts of the Continent the normal hunger for English gold has led to frequent applications, down to within a comparatively recent time, for the services of the civil engineers of this country. Too often, however, has the transparency of the device become evident only a little too late, and the men whose opinions were welcomed as oracles while the subscription list was open, were asked by what right they interfered, when all the available funds had been insured.

While rendering a full meed of tribute to the energy, perseverance, and original constructive genius that have opened a navigable highway from the Mediterranean to the Red Sea, we must not shut our eyes to the fact that the information which has been given to the public as to the actual procedure of the work has always been carefully *filtered*, not to say manipulated. It is necessary to bear this in mind, now that all we have of the undertaking is an account of the tonnage of the vessels that make use of it. But we have been given to understand, from very reliable sources, that the anticipations of Mr. Stephenson as to the deposit of sand in Port Said are fully confirmed. The actual differences of depth between two consecutive soundings, taken a few weeks apart, are so great that we do not like to mention them without being at liberty to publish the details of the surveys. To maintain a line of navigable channel, in place of a deep and commodious basin, is, we are told, the only present idea of the administration; and even this will tax the utmost energies of the dredging apparatus. Of course, this statement will be denied; but that will have little effect on the minds of English readers. We believe that it is strictly correct.

With regard to that other main link in the chain which was intended to connect London with Calcutta, English enterprise has not disdained to compete with the owners of the mules so familiar to the Alpine tourist, for the temporary traffic over Mont Cenis. The snows of the Alps have only occasionally arrested the trains of M. Fell, and he has shown himself able to contend with the minor difficulties of inclination and of traction. But the eyes of all the engineering world will be strained to watch what sort of a junction will be effected by the French and Italian engineers in the bowels of the Alps. Of the seven miles and 1,007 yards between Modane and Bardonnèche we were told some time since that the Italian half was completed, and that the Italian engineers were straining their efforts to meet their French *confrères* as far over the frontier—or rather as far under the frontier—as possible. The success of the compressed air machinery has been admirable. We confess that we look with more anxiety to the accuracy of the level than to that of the line. Unless the utmost care has been taken, on each face, to take no levels without the precaution of using perfectly *even sets*, disturbance may have been caused by the varying attractive powers of the different strata, which no means exist for checking. When even it is effected, the meeting of the two halves of the tunnel will be one of the most critical and interesting facts in the entire history of civil engineering.

It is melancholy to see how the rapid progress of our professional brothers in France—a progress that we have had repeated opportunities of watching with our own eyes, since Mr. Locke first went over to teach Frenchmen how Englishmen made railways—is arrested by the mailed hand of invasion. Not only must progress in civil works be entirely suspended, but maintenance must in many instances become all but impossible. What can now be the traffic over the Mont Cenis? What the sources of income for French railway shareholders? The unexpected, and, to our mind, extremely improvident readiness with which a new French loan has been grasped in the City, is no offset to the real depreciation of all property in public works in France. Actual destruc-

tion of works, although that may be reckoned by millions, not of francs, but of pounds sterling, is not the most serious evil; for the invaders must, for their own service, substantially repair most of the damage caused in order to arrest their march. While any debatable land exists between France under German power, and France under no power at all, havoc is likely to be made there. But the sudden check to the whole circulation of national and of international traffic is a calamity such as we have never witnessed since the Stephensons first matured the invention that we trusted would peacefully bind together the civilized world in a girdle of iron.

IRON AND STEEL NOTES.

IRON RAILS *vs.* STEEL-TOPPED RAILS.—In an appendix to the second Annual Report of the Board of Railroad Commissioners of Massachusetts, we find the following valuable letter from Mr. Abram S. Hewitt:

"NEW YORK, Dec. 15th, 1870.

"We have now reached definite conclusions in regard to steel-topped rails. We have made an inspection of every rail laid prior to January 1, 1870, on the Erie Railroad of our make, whether steel-topped or iron. You will bear in mind that the steel used for the heads is pulled, and not cast or homogeneous steel. It is necessarily of low temper, in order to secure a weld with the iron.

"It is harder and has more tensile strength than iron, but it is softer and has less tensile strength than cast-steel, even of the low grade (so far as carbon is concerned) used for Bessemer and other steel rails.

"A *priori*, it might be expected that the durability of this material would be intermediate between iron and steel—that is, more durable than iron and less so than steel. It is also intermediate in cost, and the problem to be solved is, whether iron rails, or iron rails with puddled-steel tops, or cast-steel rails are more profitable with a given volume of business.

"I think that it is now demonstrated that with a small business, where iron will endure from 12 to 15 years, iron is the more economical material; with a larger business, where iron will endure 5 years, the puddle-steel tops are the cheapest; and with a larger business, where the average life of an iron rail does not exceed 3 years, steel rails are the cheapest. Our experience is mainly confined to the Erie Railway, which comes within the third category. In arriving at this conclusion we assume that good iron rails cost $75 per ton, puddled-steel headed rails $90 per ton, and cast-steel rails $105 per ton.

"Now for the results on the Erie Railroad, premising that we have made no inspection of the cast-steel rails laid down, and can therefore institute no definite comparison with them, but we are told that the failures during the time covered by our report have been comparatively insignificant, and we believe that the report is true.

"The total number of rails delivered, prior to the date when the inspection began was 46,276 rails; of these we found in track 45,716 rails, and 560 rails were not found. Some of these 560 rails may have been overlooked in the track; but in making up the results, we have assumed them to have entirely failed, thus making the worst case for the durability of the rails.

'Again, the rails were made by several different methods of piling, some of which have proved to be better than others; and the result would therefore have been more favorable if all the rails had been made by the method which experience has proved to be the best.

"Of the total number of 46,276 rails, there were puddled-steel tops, 36,238; iron rails, 8,103; doubtful marks, 1,935; by "doubtful marks," is meant, that the inspector could not determine to which class the rails belonged.

"The average time of wear in track of these rails is 13 months; and this average time is equal for the steel-topped and the iron topped rails; so that the comparison is perfectly fair as to the time, but as a general rule the steel-topped rails were laid in places where the wear is greatest. To that extent the comparison is more favorable to the iron rails than it should be.

"The results of the inspection are as follows:—

Steel-Topped Rails.

Good rails in track	34,867	
Imperfect rails in track	833	
Failures, including missing rails	538	
Percentage of failures	1.5	per cent.
Percentage defective in track	2.3	"
Total percentage failed and defective	3.8	"

Iron Rails.

Good rails in track	6,934	
Imperfect rails in track	593	
Failures, including missing rails	576	
Percentage of failures	7 1	per cent.
Percentage of defective in track	7.3	"
Total of failed and defective rails	14.4	"

Doubtful Rails (whether Steel or Iron).

Good rails in track	1,738	
Imperfect rails in track	103	
Failures, including missing rails	94	
Percentage of failure of rails	4 9	per cent.
Percentage of defective rails	5.3	"
Total percentage of failed and defective	10.2	"

"These results go to show that these doubtful rails were mostly iron rails.

"For general conclusions, the result may be stated, that on the Erie Railroad, where the volume of business is enormous, and from the width of the gauge, the weight of the cars and locomotives is far greater than on narrow gauge roads, and the rate of speed is fully equal to any other American road.

"Fourteen four-tenths per cent. of iron rails made in the best possible manner failed in 13 months' wear, at which rate all the rails will be worn out in 90 months or 7½ years, making the average life of the rail 3¾ years.

"Three eight-tenths per cent. of puddled-steel topped rails failed, at which rate all the rails will be worn out in 342 months, equal to 28½ years, making the life of the rail 14¼ years, if we assume that the failures will go on at the same rate and that the rate of failure will be uniform for each kind of rail.

"I consider therefore that the results on the

Erie Railroad have fully justified the policy of substituting steel-topped rails for iron rails, at an extra cost of $10 per ton (in their case), and if *all-steel* rails could be had at an extra cost of $10 per ton over the cost of these steel-topped rails, I believe that a still greater economy would result.

"This conclusion still leaves open the question whether a cast-steel top may not be advantageously applied to an iron rail, but I do not consider this point of much practical importance, because I believe that all-steel rails can be made as cheaply as iron rails with cast-steel tops, and all difficulty in reworking old steel rails has disappeared with the full success of the Martin process for melting steel scrap on the open hearth of a reverberatory furnace.

"The practical result of the renewal of the eastern portions of the Erie Railway with steel-topped rails has been to reduce the requirements for new rails from 2,000 tons per month, when Mr. Gould assumed the management of the road, to about 600 tons per month at the present time. This requirement may, however, be expected to increase rather than to diminish from this time henceforth; but being reduced to so small a quantity I have advised Mr. Gould to have the Trenton works prepared for the manufacture of all-steel rails for future renewals, whereby I anticipate that the life of the track will be doubled.

"The policy adopted of getting to all-steel, by means of puddled-steel tops, by which the old rails were all made available and the outlay kept within moderate limits, is most suggestive for roads doing a large or an increasing business; and is probably the only practicable method of arriving at the ultimate desideratum of an *all-steel* track, without taxing the resources of the railway corporations beyond their immediate strength to bear.

"Faithfully yours,

"ABRAM S. HEWITT."

VERY great agitation characterized the iron market in Great Britain upon the reception of the warlike note from Russia upon the Black Sea question. The firm stand taken at first by the English Government, impelled the belief pretty generally that war was inevitable. Such an event would have resulted in a great disaster to the manufacturing interests of England, but the heaviest blow would have fallen upon the iron manufacture. Apart from the injury inflicted upon trade by the operation of a disturbed condition of the finances of the nation, which, of itself would have been of a serious character, Russia has, for a number of years, been one of England's best customers for iron, ranking second to this country only. The last five years have witnessed extraordinary efforts on the part of Russia to extend her railway system, and while some of the iron and steel requisite thereto has been manufactured at home, by the aid of heavy customs duties the rails for the purpose were nearly all obtained in England and Belgium. In the month of September of this year there were exported from Wales to Russia, 30,109 tons of rails, and for the nine months ended September 30th, 193,809 tons, against 196,671 tons in 1869, and 69,927 tons in 1868, or nearly 25 per cent. of the total exportation of rails from Great Britain. It is not surprising, therefore, that a feeling akin to a panic prevailed in Wales upon the announcement of the Russian note. The Franco-German war had been exercising a depressing influence on the trade, and rail-makers had hoped that a renewal of engagements with Russian buyers in the spring would do something toward restoring the trade to a fairly prosperous condition. This will not depend entirely upon the manner in which the Black Sea question shall be settled.

The Glasgow pig iron market was likewise affected by the same influence. Prices had recovered several shillings a ton from the lowest point, reached after the heavy decline which followed the breaking out of the war between France and Germany, when the new difficulty set in, effectually dispelling brighter anticipations, and confirming the stagnation of the trade. Pig iron warrants fell as low as 50s. 3d., but prices have recovered a little within a week.—*Bulletin of Am. Iron and Steel Association.*

RAILWAY NOTES.

LOCOMOTIVE STATISTICS.—*Michigan Central.*—The following is the report of the general average of performance of locomotives on all divisions of the road for the month of November, 1870, as made by A. S. Sweet, Locomotive Superintendent:

Number of freight cars drawn one mile	2,694,695
Equal to cars drawn over entire line	9,488
Number of freight cars drawn one mile in October	2,653,671
Equal to cars drawn over entire line in October	9,358
Number of miles run to 1 pint of oil	13.84
" " " 1 cord of wood	32.64
" " " 1 pint of oil in October	13.44
Number of miles run to 1 cord of wood in October	34.05
Average number of miles run per ton by coal-burning engines	37.37
Average number of miles run to one ton of coal in October	39 56
Average of freight trains, cars	23.26
Average size of freight trains in October, cars.	22.76
Number of gallons of oil used	2,397
Number of cords of wood used	5,549
Number of tons of coal used	2,366
Number of miles run by passenger trains	78,427
" " freight trains	127,994
Number of miles run by passenger miscellaneous trains	18,299
Number of miles run by passenger training engines	40,755
Total	265,475

Illinois Central.—The report of S. J. Hayes, Superintendent of Machinery of the Illinois Central Railroad, for the month of October, 1870, affords the following:

Passenger trains	112,475
Freight	302,559
Construction, etc	14,861
Switching	53,063
Total	482,958

The cost per mile run was:

For oil and waste	0.83 cts.
For fuel	7.33 "
For engineers and firemen	5.99 "
For cleaning	1.07 "
For repairs	9.01 "
Total	24.23 cts.

Cost per mile run, in cents:

Passenger engines	16.80 cts.
Freight engines	27.05 "
Construction engines	14.87 "
Switching engines	19.50 "

Average number of miles run to

Pint of oil	13.07
Ton of coal	34.83

179 locomotives made mileage during the month. This report is for 974 miles operated. Nine locomotives have had general, or thorough repairs, and seven are undergoing repairs.—*Railroad Gazette.*

THE SHENANDOAH VALLEY RAILROAD.—The preliminary surveys and estimates for the proposed Shenandoah Valley Railroad are completed and are embodied in a report from the Engineer-in-Chief, W. W. Wright.

The total length of road is 233 miles; the cost per mile is estimated at $30,000, making a total of $6,990,000.

Of the country traversed and the prospective business, Mr. Wright says:

"The magnificent Valley of the Shenandoah, ranging from 30 to 40 miles wide, and extending from the Potomac river to and beyond the southern terminus of our road, is so well and favorably known that an extended description of its resources is superfluous. No richer agricultural region is to be found in the whole country, and roads as expensive as ours have been constructed in other sections for the accommodation of an agricultural business alone no greater than will be commanded by our line. But in addition, we pass for a long distance through a mineral region of almost unsurpassed value. Iron ore of the best quality and in great abundance is found contiguous to our road, and even with the present difficult and expensive means of transportation, it is manufactured to a considerable extent, and with profit. With railroad facilities for transportation to market, there is no section of the country that can manufacture iron with larger profit than the Shenandoah Valley. As an evidence of this, the principal manufacturer there says, "give us a railroad, and we do not need a protective tariff to enable us to compete with foreign iron in the market." Possessing such advantages as this valley does, can there be any doubt that the iron interests will have great development as soon as the railroad is completed, and furnish a heavy item of business to the road?

"Then the thousands and thousands of acres of white oak, whi e pine, and other valuable timbers, that are now almost worthless, will, with railroad facilities for transportation, at once have such a market value that lumber to a large extent will be manufactured and shipped over the road to the many points that can be supplied more cheaply from this source than any other.

"Not only for the purpose of cutting up this timber, but for any other kind of manufactories, the Shenandoah river furnishes as fine a water-power as can be found anywhere. The volume of water is ample and constant—the river being from 200 to 300 ft. wide and 6 to 8 ft. deep—and the fall at the rate of 5 to 7 ft. per mile. Our line in its general course adheres so closely to the river that it will be easily accessible to the manufacturing establishments that will spring up all along the route, and thus a large and valuable source of business will be created and constantly extended.

"There are various other important items of business that will come to our road which the limits of this report prevent me from naming in detail, but there is one which I ought not to omit. The Valley of the Shenandoah contains some of the most celebrated natural curiosities in the country—conspicuous amongst which are Weyer's Cave and the Natural Bridge—and the adjacent mountain ranges have a world-wide celebrity for the abundance, variety and medicinal value of their Mineral Springs. The travel to and from these popular places of resort will furnish no insignificant revenue to the road.

"From my knowledge of the business of other railroads, I am satisfied that the *local business alone of the Shenandoah Valley is amply sufficient to furnish a good paying business to a railroad that can be constructed for what ours is estimated to cost.* But in addition to this we have another important source of business already created and ready to our hands in the railroad connections that we make. Fortunately for our road, though unfortunately for the interests of the Valley, the construction of railroads heretofore has been *across* the Shenandoah Valley. Starting from the Potomac river, we cross in succession with our line the *Baltimore and Ohio*, the *Winchester and Potomac*, the *Orange, Alexandria and Manassas*, the *Chesapeake and Ohio* railroads, and intersect with the *Virginia and Tennessee Railroad.* These five cross-lines will become in reality feeders to our *Great North and South Line*, which it requires no great gift of prophecy to see will become the great connecting line between the South and South-west and the northern centres of population and trade.

"With such a prospective business there can scarcely be a doubt of the value of your enterprise, and it is fortunate that this is so well understood and fully appreciated by those who have it in charge, that they are resolved to proceed promptly with the work of construction."

THE NEW MINING LOCOMOTIVES.—The Baldwin Locomotive Works have had on exhibition for the last three days two mining locomotives, ordered for the Wilkesbarre Coal and Iron Company's collieries in the third anthracite coal region. Mr. Parrish wishes to find some substitute for the mule as a carrier in the mine. During a strike or other suspension of work, a large stud of mules is a great expense. A locomotive costs nothing when it is doing nothing, and if well cared for does not grow old. Another outlay is saved in the item of drivers. One man suffices to drive a locomotive; and a few couplers to handle an entire train. The fire-box is square and deep, and so little stoking is required, that the fire door need not be opened more than four or five times during the entire day. While the locomotive was standing on the track in the shop, the steam gauge indicated 120 lbs. pressure in the boiler, and yet the engineer had laid a damper plate over the chimney hole. Had the chimney remained open the safety-valve would have deafened the shop. It seemed difficult to explain this excellent draft; but it was an evident fact. The machine was run across the floor at various speeds, started with ease, and stopped in the space of a foot or two. There was an appearance of perfect docility about it, which relieved us from all suspicion of accidents underground.

On examining the working gear, this little locomotive appeared to be as staunchly built and well finished as any passenger engine, but was entirely

without ornament. The wheels were necessarily small, but heavy, with a broad, flat thread, and very light flange. The two cylinders, 9 in. in diameter (inside) by 12 in. stroke, lie under the front end of the boiler. The piston rods play between groups of 4 square slide rods, and a simply adjusted linkmotion works just forward of the fire-box. The connections are of course inside, on the cranked axle of one of the two pairs of drivers (of 30 in.), which are the only wheels. The fire-box and low platform overhangs behind. As coal is always at hand, no coal space is needed, and the water-tank is folded over the top and sides of the boiler, acting as a jacket, and feeling quite hot to the hand.

This tank holds 190 gallons, and the whole engine, with fuel and water, weighs nearly 15,000 lbs. The makers guarantee that it shall haul, under all circumstances, with wet and dirty rails, on a level, 340 gross tons; on a 60 ft. gradient, 80 gross tons, and on a 100 ft. gradient, 50 gross tons. Under favorable circumstances it will of course do more.

The fire-box platform is covered with a light wagon-top roof to guard the engineer's head. The extreme height is 5 ft. 4 in.; extreme width, 5 ft. 1 in.

Several engines, somewhat similar to these, have been constructed in Pittsburg, and used in the mines of that neighborhood, giving satisfaction. These are somewhat simplified; but not to such an extent as to interfere with their being taken readily to pieces, examined, or repaired. It is needless to say that they are made with conscientious care, and made strong, to bear rough usage at the hands of ignorant or thoughtless persons.—*United States Railroad and Mining Register.*

ORDNANCE AND NAVAL NOTES.

NEW FIELD GUNS.—An experimentnl 16-pounder muzzle-loading field gun on the Fraser principle is now in course of construction at Woolwich. It is designed for a competitive trial with a bronze gun, with which it is to correspond in weight, length, bore, rifling, weight of projectile, and charge of powder. The weight is to be 12 cwt., the bore 3.6 in., weight of projectile 16 lbs., and the charge of powder 3 lbs. The rifling will be in three grooves, on a pattern recently adopted. The only difference between the two guns will be in the nature of the metal, and in the contour of the piece. The Fraser gun is already in hand, and the other will soon be commenced. The former will consist of a steel tube, forming in itself a perfect gun, but reinforced for about half its length in the rear portion with a jacket of coiled wrought iron. The bronze gun will simply consist of that metal, cast in the desired form.

The two guns being thus made on exactly the same pattern, with the bare exception of the external contour, it would seem that until wear and tear produce a difference the competitive pieces must give very similar results, unless there is some diversity in the charge of powder or the projectile. If the bronze gun will bear its charge of 3 lbs., there can be no doubt that the gun of steel and iron will bear a heavier charge. In the latter case we should look for increased range, a flatter trajectory and greater precision. But so far as we can learn at present, the charge of the Fraser gun is to be kept down to the capability of the bronze gun. The competition, therefore, is of a limited character, one gun being allowed to do its best, whilst the other is kept below its power.

The muzzle-loading Fraser guns of 3 in. bore, which, after lying by for some time, have lately been rifled, and now called 9-pounders. In former days they would have been ranked as 12-pounders. There are about sixty of these guns. In weight and bore they correspond to the Indian gun; but they are quite capable of doing duty as 12-pounders, while it is tolerably certain that the bronze gun would be found unfit for the latter purpose, although the Indian gun corresponded in bore to the old 12-pounder. It is said that the Indian gun gives better results with a 9-pound shot than with one of 12 pounds. The question, we presume, is simply one of proportion between powder and shot. We may get the right proportion either by reducing the weight of the shot or by increasing the weight of the powder charge. Of course we are speaking within certain limits. But we would ask, why is it that the bronze gun cannot take the charge proper to a 12-pound shot, whereas the gun of wrought iron and steel, having the same weight and calibre, is able to do so?

The urgent necessity for increasing the power of our field artillery is rendered painfully evident by recent events on the continent. Are we, then, wise to use a metal which—weight for weight and bore for bore—gives the lesser power as compared with the built-up gun of steel and iron? As for breech-loading, it is sufficiently clear that more is lost than gained by employing it in our artillery, valuable as it undoubtedly is when applied to small arms. For the rifle and the mitrailleuse, breech-loading is invaluable. But the rapidity of fire which breech-loading confers on small arms disappears in its application to field artillery; while, whatever other merits it may possess, a field piece on the breech-loading principle is peculiarly liable to be disabled by some derangement of its apparatus, the complicity of which is also likely to be very embarrassing in the excitement of action.

With regard to the use of steel in the service guns, it may be needful to observe that this metal is not relied on as an element of strength. In our great guns steel serves as a lining, giving the necessary surface, and offering a better resistance than iron to the erosive action of gunpowder. The necessary strength is obtained by the use of coiled wrought iron which envelops the steel tube. In the experimental 16-pounder the forward part of the gun is of bare steel, the tube protruding from the wrought iron envelope. In a gun of this size, the steel is thought sufficient by itself towards the muzzle, where the strain is least, but the wrought iron is added towards the breech where the strain becomes severe. There are facts on record which show the necessity of being very guarded in the use of steel where the force of gunpowder is concerned.

Passing from the consideration of steel and iron to that of bronze, it seems curious that the latter should receive any degree of preference as a material for our field guns, seeing that bronze is discarded at the two extremities of the scale, namely, the rifle and the heavy gun. At the present time we need, as far as possible, to combine in our field artillery the accuracy and range obtainable on the principle of the rifle with the greatest practicable weight of shot. Not that mere weight of projectile is of itself a special advantage in firing against

troops; but this weight may be made to represent enhanced destructiveness in the effect of explosive shot. In number of guns our field artillery is lamentably weak. So far, this gives us an opportunity for introducing new and effective weapons corresponding to the era in which we live. The lure of "cheapness" must be steadily resisted on this point. The great cost of our field artillery is not the guns, but the men and the horses. It has recently been shown in these columns that the yearly cost of a troop of horse artillery is at the rate of £6,000 per gun. On such a foundation we ought not to rear a superstructure simply "cheap." Moreover, nothing is cheap in war that is not effective, and effectiveness demands something more than mediocrity. Positive inferiority is certainly to be avoided. But if we are coming into the field with bronze guns, the War Office can scarcely be said to have learned aright the story of Sedan.—*Standard.*

In the recent great sortie made by the French from Paris, General Ducrot brought into action one of those new engines of destruction to the invention of which the present war has given so great an impetus. This is an armor-plated locomotive, furnished with two powerful mitrailleurs, also protected by armor, and originally intended for the railway bridge at Point du Jour, whence it was to throw bullets on to the heights of Meudon. This novel machine, which weighs altogether only some six tons, has been manufactured at Cail's, the well-known mechanical engineer of Paris, to whose establishment the city is so much indebted for the extraordinary efforts that have been made to supply it with cannon and other means of defence. The Prussian invasion has certainly contributed a great deal to develop the inventive talents of the French; for hardly a day passes without some new implement of destruction being submitted to the Government of National Defence. Under the spur of defeat they have produced the Marekderberg mitrailleur, firing 250 balls a minute, and the Montigny, firing 480, as well as the Durant steam mitrailleur, which discharges no less than 4,500 in the same space of time, and the Frauche use, or "mower," which is said to operate without noise, smoke, or fire, to have a range of from 500 to 600 yards, and to cost only 35f. with all the necessary apparatus for firing 300,000 projectiles; so that, if every bullet really had its billet, the French by employing this weapon might rid themselves of the whole of their enemies for something less than 100f. In addition to the above, many novel descriptions of shells have also been proposed, if not actually tried, among which are the Gaudin fire-bomb, the improved Menestrol shell bombs emitting suffocating vapors and so on.—*Pall Mall Gazette.*

We understand that the French are fully alive to the fact that their system of field artillery is inferior to that of the Prussians, and that they are making strenuous efforts to improve their material. In fact, the sole merit of the French system is its simplicity. Their field piece, as a muzzle loader, compares favorably, both in mechanism of gun and in simplicity of ammunition, with the more complicated breach-loader of the Prussians. Here, however, the superiority ends. In accuracy, in flatness of trajectory, and in hard hitting, the Prussian field piece is by far the more powerful weapon. Much of this is due to the calibre. The French *canon raye de* 4 is a bronze muzzle-loader converted into a rifled gun by grooving the old 6-pounder smooth-bore, the calibre of which is 3.4 in. The calibre of the Prussian steel 4-pounder is, however, only 3.1 in.; its projectile, consequently, although of the same weight, is of less sectional area than that of the French gun. The Prussian shells are, therefore, better adapted to overcome the resistance which the air opposes to all bodies moving through it, and the result is that they lose less of their original velocity, and, consequently, hit harder at a distance. It is easy to prove that the atmosphere offers resistance to bodies passing through it, and that the amount of this resistance depends in a great measure on the velocity or rate at which the body may be moving. If we take a book, open it, and, having placed one page upright, pass it forward, the page will shut by the resistance of the air. In walking in the open air on a clear calm day we experience very little resistance from the atmosphere; a canter on horseback, however, produces a refreshing current, and we feel a breeze, as it were, against the face; while on the same day, if we put our head out of a railway carriage, we are obliged to press down our hat firmly to prevent its being blown off. To all appearance, however, there is no wind. We can understand, therefore, the enormous resistance which a shot must experience, travelling as it does ten times as fast as the fastest train. This resistance, moreover, is considerably influenced by the shape of a shot. As the bluff collier stems the current with difficulty as compared to the taper yacht, so the dumpy, ill-proportioned projectile meets with a greater resistance than one formed on more scientific principles.—*Globe.*

ENGINEERING STRUCTURES.

International Industrial Exhibition.—The proposed building for the proposed International Industrial Exhibition is thus described in a little pamphlet containing the prospectus of the Company:

The site of the Palace of Industry embraces four full blocks (forming an area of about 23 acres) uncut by any streets, situated between Ninety-eighth and One Hundred and Second streets, the Third and Fourth avenues, and accessible by the horse cars of the Third, Fourth, Second and Madison Avenue Railroad Companies; and also by the steam cars of the Hudson & Central, the Harlem, and the New York and New Haven Railroad Companies—all of which will shortly pass its western boundary, on their way to the Great Union Depot.

The position, separated only by a narrow strip of land from the Central Park, is lofty, and commands a beautiful panoramic view on all sides.

The improvements of the vicinity for the ensuing three years will probably increase the value of the property several millions. As an operation in real estate, it is profitable.

This Palace of Crystal is designed to be a marvel of beauty and grandeur, sufficient in extent to accommodate readily 70,000 persons; and it will be arranged as a Repertory of the Art, Science, Invention and Industry of the world. Within its long and lofty halls will be arranged and classified the various products of the earth. Art will display her paintings and her statuary. There will be

gardens, with tropical plants and birds, and fountains; halls where music or lectures can be heard. All these and many other attractions will here combine to teach the intellect and delight the imagination.

There will be no restriction of expenditure, which would mar any of its proposed attractive features.

The building will run around the ground, and be in depth 150 ft., and eight (8) stories high above ground.

There will be a court of eleven (11) acres in the centre.

The court will be covered with glass, and from roof to floor will be about 120 ft.

This court will be used as a Horticultural Garden.

The upper story of the building will be an Art Gallery, with skylight opening through the top.

The width of the Art Gallery will be 150 ft., and the length will be 3,760; or two rows of paintings, which will give 7,520 ft. of wall or space in length, on which to exhibit paintings.

The second story from top will be given free to Artists as studios, or such space of same as may be needed; and a library will be included on each floor.

There will be four Observatories—one at each corner of the building.

THE TEHUANTEPEC SHIP CANAL.—The following is an epitome of the ship canal concession, which passed the Mexican Congress on the 13th of December and has now become a law:—

ARTICLE 1. Authorizes the Tehuantepec Railway Company to construct a ship canal and its appurtenances, in addition to its railway, across the Isthmus of Tehuantepec to connect the waters of the Gulf of Mexico with the Pacific Ocean. The canal is to be of a depth sufficient to pass ships drawing 19 feet of water, and the concession is for 99 years; the Mexican Government to protect the execution, preservation and security of the work.

ART. 2. Explorations and surveys to be completed within 3 years, and plans and profiles to be submitted to the President of Mexico for approval. Work on the canal to be commenced within one year after the plans are approved.

ART 3. Requires a bond from the company in the sum of $50,000 that plans shall be presented within 3 years.

ART 4. The obligations of the company to do the work required may be suspended by a fortuitous case or by *force majeure*.

Provision is made for the proper notices to be given the Government of the removal of the impediments and the recommencement of the works.

ART 5. Right of way free and one-half of the public lands within 5 miles on each side of the canal in aid of its construction.

ART 6. May take private lands for use of company whenever necessary, by indemnifying the owners according to law, but may take public lands and material gratis.

ART. 7. During the construction of the canal the company may import on the Isthmus the materials, machinery, tools, coal, carriages, and other useful articles duty free, and after the canal is completed the company may import, duty free for 99 years, the machinery and hard coals that it may require.

ART 8. For 99 years the Mexican Government will exact no contribution for transit through the canal, nor on the capital invested therein; after that time the works become the property of the Government.

ART 9. After 20 years the Government will be entitled to 20 per cent. of the net profits when dividends are paid to stockholders

ART 10. Tariff and regulations governing the use of the canal and other works to be made by the company and submitted to the President of Mexico for his approval.

ART. 11. The company to build two lighthouses, one on each coast, which are to become the property of the Government.

ART 12. The transit through the canal shall be free to all the inhabitants of the globe. All nations may use it in time of peace for transportation of their troops, munitions and vessels of war; but its entrance shall be vigorously closed to troops, munitions and vessels of war belonging to nations which may be at war with one another or with others.

The canal shall be neutral and open to all nations at peace with the Republic of Mexico, but the transit and other dues shall be increased 25 per cent. on vessels and merchandise belonging to nations having no treaty of neutrality with Mexico with respect to the transit by the canal.

ART. 13 The direction and management of the canal shall belong to the company, but the Government reserves the right to appoint one-fourth of the number of directors, who shall have the same prerogatives as those elected by the stockholders.

The company shall make an annual report the President of Mexico.

ART. 14. The company, though formed abroad, shall be deemed exclusively Mexican, and, if it thinks proper, may form separate companies for the carrying out of its several operations, and may organize said companies either in the republic of Mexico or in the United States, under general or special laws of the place where formed.

ART. 15. All persons now and hereafter engaged in the enterprise are to be regarded as naturalized Mexicans.

ART 16. The restrictions of the previous articles shall not affect differences arising between aliens and stockholders outside of the republic, nor shall the decisions of foreign tribunals affect the provisions of this law nor Mexican interests.

ART. 17. The company cannot transfer, alienate or mortgage the concession, nor the canal and its accessories, without the consent of the Mexican Government, and in no case can it be done to a foreign government, nor can a foreign government or State become a partner in the enterprise. The company may issue and sell bonds and other obligations without the approval of the Government in such amounts and at such prices as it may see fit; and may mortgage the canal and its accessory works to private individuals or associations.

ART 18. The grant shall become null and void:

First—If the surveys and plans of the canal are not made within 3 years.

Second—For not commencing the works within 1 year after the plans are approved by the President of Mexico.

Third—If $1,000,000 are not expended in the first year after the works have been commenced, and $3,000,000 per annum thereafter until the

works are completed, except in case of *force majeure* duly proved.

Fourth—For violating any of the expressed provisions of this law as enumerated.

Fifth—In case of forfeiture of the railway concession.

Sixth—In case of neglecting for 365 consecutive days to keep the canal open for use.

ART. 19. In case of forfeiture of grant the company shall lose the concession, but will retain as its own property, until the expiration of 99 years, the works which it shall have constructed; but the successors of this company shall have the right to take the same at an appraisement.

ART. 20. All doubts and controversy as to the interpretation or execution of this law will be decided by the competent federal tribunals of the Mexican republic.

ART. 21. The company shall appoint a representative, to reside in the City of Mexico, who shall have power and instructions to treat with the Federal Government and other authorities upon all matters included in the present concession.

NEW BOOKS.

A MANUAL OF THE MECHANICS OF ENGINEERING AND OF THE CONSTRUCTION OF MACHINES, with an introduction to the calculus. Designed as a text-book for technical schools and colleges, and for the use of engineers, architects, etc. By JULIUS WEISBACH, Ph.D., of the Royal Mining Academy of Freiburg. Vol. 1. Translated from the last German edition by ECKLEY B. COXE, A.M., Mining Engineer. New York: D. Van Nostrand.

The superior excellence of this great work on mechanics lies not alone in the fulness with which each and every topic is treated, but also in the thoroughly practical application of deduced principles and formulas.

There are many works on mechanics which afford good mathematical discipline to one who is seeking to gain expertness in the line of independent scientific investigation, or who is desirous of giving that finish to his mathematical acquirements which the standard of modern literal culture requires. Such works accomplish the ends designed without satisfying the demands of him who has adopted the profession of engineering. The technical student and the practising engineer both require not only the conclusion to which the theoretical investigation leads, but the useful application of the result, and the modification of it, which the exigencies of practical life may require.

The student will find in the work before us a logical arrangement of topics, and a progressive gradation of mathematical applications which satisfies his utmost need in the way of mental training; and the practical engineer may find the formulas deduced and applied in every recognized department of engineering.

It is 24 years since the appearance of the first German edition. The present American work is translated from the fourth German edition, with the advantage over the latter of some emendations afforded the translator by the author.

An introduction to the calculus begins the present volume, and affords the pupil the elementary drill sufficient to follow all the subsequent applications of the higher mathematics in the work.

Then follows a section on the purely mathematical theory of motion, in two chapters, extending over 50 pages, after which follows the physical science of motion in general; of this section there are 40 pages. The illustrations by diagram (there are more than 50 in these two sections) of resultant motion are most admirable.

The next section treats in 5 chapters respectively of the statics of rigid bodies; the centre of gravity; equilibrium of bodies rigidly fastened and supported; equilibrium in funicular machines; the resistance of friction; and the rigidity of cordage.

Section 4 is devoted to "the application of statics to the elasticity and strength of bodies." There are 5 chapters also in this section, devoted respectively to elasticity and strength of extension; compression and shearing; elasticity and strength of flexure or bending; the action of shearing elasticity in the bending and twisting of bodies; the resistance of columns to crushing by bending or breaking across; combined elasticity and strength. This important section covers over 200 pages, and closes the subject of statics of solids.

The dynamics of rigid bodies naturally follows, and beginning with the discussion of the moment of inertia the author applies the analysis to lines, surfaces, and solids, in the most exhaustive manner. This section (5th) includes also chapters on centrifugal force; the action of gravity on bodies moving in prescribed paths, and the theory of impact.

Section 6th treats of statics of fluids, and, in addition to the more general principles of hydrostatics and aerostatics, elucidates the theory of floating bodies, their buoyancy and stability. The work done by compressed air is the leading topic of the last chapter (4th) of this section.

The dynamics of fluids forms the subject of the closing section of this first volume. It is divided into 9 chapters, treating successively the following topics, the mention of which will sufficiently indicate their important practical bearing: The general theory of the efflux of water from vessels; the contraction of the vein or jet of water when issuing through orifices in thin plates; the flow of water through pipes; resistance to the motion of water when the conduit is suddenly enlarged or contracted; the efflux of water under variable pressure; the efflux of air through pipes; the motion of water in canals and rivers; the theory of measuring water; the impulse and resistance of fluids.

This section alone is embellished with 206 illustrations, and it abounds, moreover, with tables of constants derived from experiment that are of the highest value to the hydraulic engineer. An appendix treating of the "theory of oscillations" appears in the present volume, although wanting in the latest German edition, this chapter having been recently written by the author.

When employed as a text-book in our colleges and higher scientific schools much of each section must be necessarily omitted, the work is so voluminous; but as all of the amplification of a subject by this author is designed to afford aid to the learner, so the student of Weisbach, whether in the school or out of it, is never confused by the extent of the subject or the number of applications. Students who are familiar with algebra and trigonometry may read almost the entire work without the treatise on calculus which begins this volume.

An example of the author's method taken from

the second volume will be found in another place in the present number of the MAGAZINE.

A RUDIMENTARY MANUAL OF ARCHITECTURE, being a History and Explanation of the principal Styles of European Architecture, Ancient, Mediæval, and Renaissance. By THOMAS MITCHELL. London: Longmans, Green, & Co., 1870. For sale by Van Nostrand.

In his preface to this volume, Mr. Mitchell explains that the object he had in view in publishing it, was rather to lead the students on to further research than to attempt any comprehensive scheme of instruction. The latter course would, indeed, have involved far more labor, and expanded the book greatly beyond its present limits, but we doubt that it would have been beyond the capability of the writer. In fact, we read Mr. Mitchell's manual wishing it were something more, yet willingly testifying that he has at least fulfilled the promise contained in the title of his book.

The first chapter is devoted to the early history of architecture, and in this Mr. Mitchell points out that in the various styles of construction peculiar to different countries can be traced out the primitive habits of life of the various races at the commencement of their existence. The first rude habitations which sheltered primæval man—the cave, the tent, the hut of logs—were the foreshadowings of those structures which should in future ages be developed into the lasting monuments of civilization, more enduring than the nations that had reared them. The temples of Assyria and Egypt, massive as the hills, the ruins of the architecture of Greece, bringing more plainly in their decay the first ideas which gave them birth, the light fantastic palaces of the East, all these speak of the outlines of their first types, the rock-hewn shelter, the rough timber dwellings, the skin-covered tents of the hunting, the pastoral, and the agricultural tribes. Tracing the development of European architecture from its rudest outlines to its most finished and harmonious proportions, Mr. Mitchell proceeds to sketch out the progress of the Greek, the Roman, and the Byzantine styles, and to show how the classic rules diverged and extended into the most beautiful and picturesque of all orders, Gothic, with its interminable variation. The larger portion of the book is devoted to this part of the subject, and great credit is due to the author for the skill with which he has selected his information, at once the most valuable and the most concise. Numerous engravings are introduced, well executed and necessary for the illustration of the text, but this latter feature extends throughout the book, and adds greatly to its value. With a chapter on Elizabethan and Debased Gothic, and another on Renaissance, Modern Italian, and Modern Architecture, the manual concludes. We must not omit to notice, however, the appended glossary containing 600 terms, and which will be found of service, although it cannot be regarded as an architectural dictionary. Altogether, Mr. Mitchell's book is entitled to take a first place among the numerous manuals which are now being produced so plentifully.—*Engineering.*

INTRODUCTION TO THE STUDY OF INORGANIC CHEMISTRY. By W. A. MILLER, M.D., D.C.L., LL.D. London: Longmans & Co. For sale by Van Nostrand.

This is one of the useful and carefully edited "Text-books of Science" publishing by Messrs. Longmans. It possesses a melancholy interest as being the last work from the pen of the late Dr. Miller, who says, in the preface, that it is written expressly for beginners; and, in order that they should really understand the statements which it contains, it will be necessary for them to begin at the beginning and to go straight through it. The elements and chemical notation are first clearly explained, and the student is then inducted into the mysteries of atmospheric air, water, carbon, and the other non-metals; the second division being occupied with the metals. More than 250 experiments are described, and numerous wood-cuts given. As a specimen of the manner in which the metals are described, we extract the following:

"Aluminum: *symb.* Al; *Atomic wt.* 27; *sp. gr.* 2.67.—This metal derives its name from alum, of which material it constitutes between 5 and 6 per cent. Its compounds are among the most abundant constituents of the rocks, including felspar, hornblende, and slate. Aluminum may be obtained from cryolite ($3\ Na\ F, Al\ F_3$) by fusing it with sodium; but the method usually practised consists in decomposing sodic aluminic chloride ($Na\ Cl, Al\ Cl_3$) by heating it with sodium; an intense action occurs, and the aluminum is obtained in a melted state under the fused sodic chloride—

$$Na\ Cl\ Al\ Cl_3 + 3\ N\ A = 4\ Na\ Cl + Al.$$

Aluminum is a white malleable metal, resembling zinc in color and hardness. It may be rolled into foil and drawn into wire. When struck, it gives a clear musical sound. It melts at a temperature below that needed for the fusion of silver (1023° C.) It preserves its brightness in the air, and is but slowly oxidized at a red heat. Nitric acid attacks it with difficulty, but it is rapidly dissolved by hydrochloric acid, and by solutions of the alkalies, hydrogen being given off. This metal, with about 90 per cent. of copper, forms a golden yellow alloy, called *aluminum bronze*, well fitted for castings."

The various salts of aluminum are then described, and experiments given to prove the correctness of the statements made. The proof sheets were seen through the press by Mr. C. Tomlinson, at the request of Dr. Miller. The book is clearly printed, and is one of the best introductions to inorganic chemistry for beginners with which we are acquainted.—*English Mechanic.*

ELEMENTARY TREATISE ON NATURAL PHILOSOPHY. By Professor A. PRIVAT DESCHANEL, of Paris. Translated and edited, with extensive additions, by Prof. EVERETT, D. C. L., of Belfast. In 4 parts. Part 1—Mechanics, Hydrostatics, and Pneumatics. London: Blackie & Sons. For sale by Van Nostrand.

This translation of Prof. Deschanel's "Traité de Physique" will, we believe, be found extremely useful. An elementary treatise of moderate size on Physics has been long wanted in our schools. Atkinson's translation of Ganot, or Brook's Natural Philosophy, is too expensive for general use, and of smaller books, none, so far as we know, are good. The issue of Dr. Everett's translation in parts at the moderate price of 4s. 6d., will enable it to be largely employed. The engravings with which the work is illustrated are especially good, a point in which most of our English scientific works are lamentably deficient. The present part contains Mechanics, Hydrostatics,

and Pneumatics. The clearness of Deschanel's explanations is admirably preserved in the translation, while the value of the treatise is considerably enhanced by some important additions. Thus, to Deschanel's description of the pendulum is added a short account of the condition of isochronous vibration, moment of inertia, momentum, and kinetic and potential energy. In the section on Pneumatics, Deschanel's extremely good description of the air-pumps of Hawksbee, Bianchi, Kravogl, Geissler, and Deleuil, is supplemented by an account of Sprengel's mercurial pump. It is possible to point out defects, but they are few. The conception of "mass" is always a difficult one for a beginner. Deschanel gives a very clear explanation, which is not reproduced, the term being employed without explanation. Nor do we understand why, instead of Deschanel's statement that the co-efficient of absorption of ammonia in water at O°C. is 1050 (exactly it is 1150), it is said to be only 600. But these are minor defects, and we repeat that we believe the book will be found to supply a real need.—*Nature.*]

A Text-book of Elementary Chemistry, Theoretical and Inorganic. By George F. Barker, M.D., Professor of Physiological Chemistry in Yale College. 12mo, pp. vi, 342. New Haven: Chas. C. Chatfield & Co. 1870.

In this text-book, Professor Barker has rendered a service which cannot fail to be gratefully appreciated by all those whose office it is to teach the principles of chemistry, and especially by those engaged in instructing college or academic classes, where, from the comparatively limited time that can be spared for the study, and in accordance with the educational aims of the institutions, the object is to give the student clear and accurate knowledge of the fundamental principles of chemistry as a science, and its most important practical applications and results, rather than to attempt a technical and thorough mastery of the subject. The latter must be gained in the laboratory, and by months, or even years, of patient labor and study. But in the thorough systematizing of principles and their results, in its admirable nomenclature, in its delicate and precise methods of research, and by the insight it gives into the phenomena of daily experience, chemistry forms an invaluable instrument of intellectual discipline, and its study an indispensable part of a complete education.

A radical defect of most of the text-books of chemistry hitherto has been that the principles of the science have not been presented in a systematic and prominent manner, but have been scattered at hap-hazard in the mass of fact and detail, and so have in a measure been obscured and lost sight of in teaching.

This evil, Professor Barker has happily and completely avoided. The first part of the book, about one fourth, is devoted to Theoretical Chemistry, and the subject is developed from simple principles and careful definitions into a clear and definite system. The admirable generalizations of the new chemistry are given with great perspicuity and conciseness, and are illustrated with numerous examples.

The second part is devoted to Inorganic Chemistry, the most important of the elements being discussed in regard to their distinctive chemical qualities, their combinations, and their economic uses. The electrical relations of the elements, a matter of fundamental importance in the new chemistry, are made the basis of the order of treatment in the book, the imperfect and ill-defined classification into metals and metalloids, or into groups formed upon analogies or resemblances, being thus avoided. Copious experimental illustrations of the various points are described, and made intelligible and attractive by numerous cuts.

The treatment of the subjects in this part of the work is marked by the same clearness of description and conciseness of statement as in the first part, and these qualities, as well as the fulness of its matter, render the book most valuable, not merely as a text-book, but also as a convenient manual of reference for the advanced or professional student.

We have only space to add a word respecting the mechanical execution of the book, which in respect to clearness and elegance of typography and handsome press-work is all that could be desired.—*College Courant.*

MISCELLANEOUS.

Sub-permanent Magnetism Experiment.—The following experiment may be interesting or useful to some of your readers. The object of the experiment is to produce, in a few minutes, what Dr. Tyndall has named sub-permanent magnetism; and thus represent to a class *quickly* what is effected by the earth *slowly* in soft iron lying in the magnetic meridian, and subject to molecular disturbance from percussion or other causes.

The requisites for the experiment are—a block of cast-iron (wrought-iron might, perhaps do) slightly magnetized, a bit of soft iron wire, a hammer, and a magnetic needle for testing the wire.

Expt. 1.—Lay the iron wire on the block, and hammer it lightly from end to end, for a few seconds. Presented to the needle, the wire will be found magnetized, showing distinctly strong N. and S. poles, produced by the S. and N. poles of the block.

Expt. 2.—Place the wire *reversed* on the block, i. e., lay the N. pole of the wire on the N. pole of the block, and hammer as before. Tested again by the needle, the wire exhibits its poles reversed.

Expt. 3.—Lay the wire as in Expt. 1, and hammer; the original polarity is restored. Finally, by changing the position of the wire, the pole may be changed and rechanged as long as the wire lasts.

This experiment would seem to represent well the magnetizing action of the earth. The block personates the earth with its magnetism, which is not less comparatively than that of cast-iron. Were the wire to remain for a considerable time lying on the block, it would be magnetized. The hammering effects *quickly*, in the whole wire, that molecular disturbance which is slowly, and piece by piece, produced in great masses of iron standing on the earth. E. Kernan.—*Chemical News.*

The Russians assert that they possess a breech-loading rifle which is far superior in all respects as a military weapon to our Martini-Henry. We understand that our authorities have been made acquainted with this fact from information which has reached them from St. Petersburg.—*Army and Navy Gazette.*